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FOOD TECHNOLOGY

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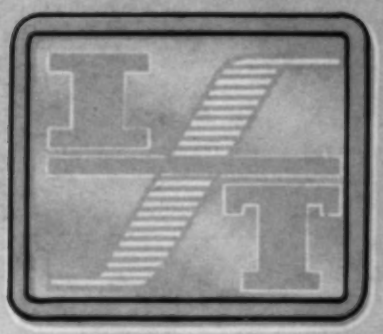

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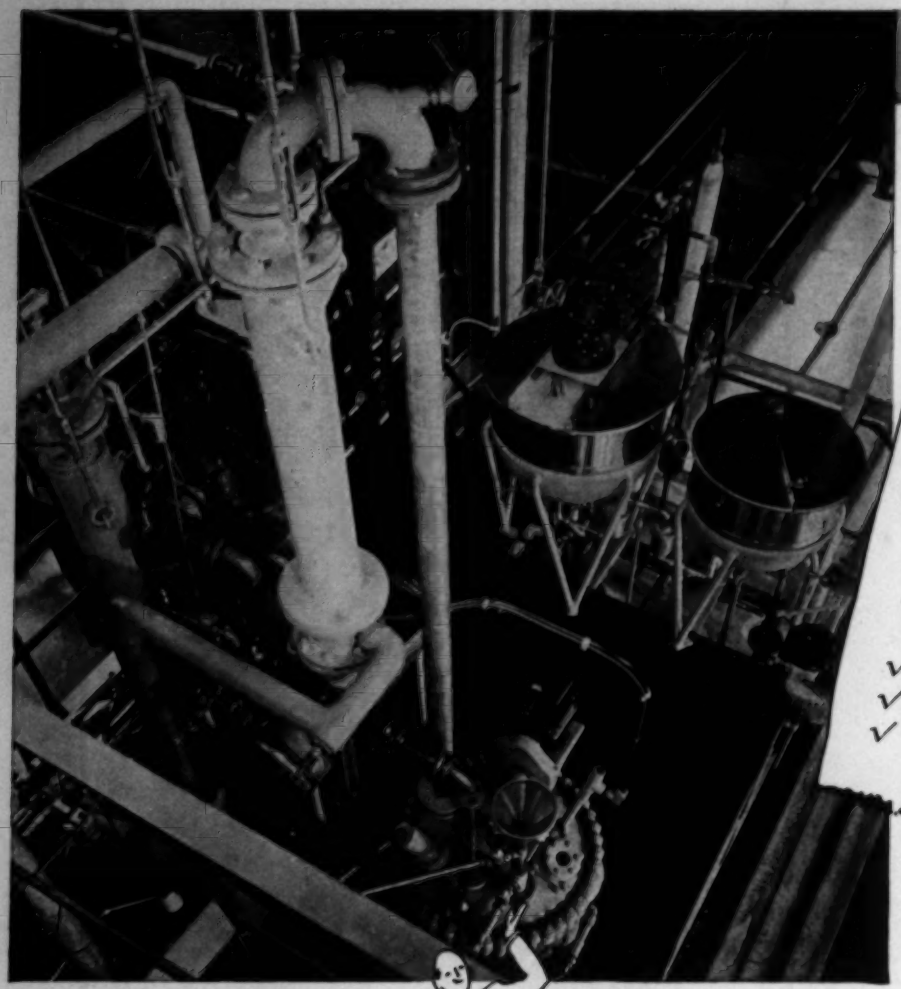

TYPICAL FOOD INSTALLATIONS PFAUDLER HAS ENGINEERED

★

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- ✓ Ice Cream Plants
- ✓ Beverage Plants
- ✓ Brewing Stock Houses
- ✓ Mayonnaise and Salad Dressings
- ✓ Extracts
- ✓ Meat By-Products
- ✓ Syrup, Concentrates, etc.

Above: Pfaudler stainless steel kettles (top right), stainless steel heat exchanger and glass-lined reactor with accessory equipment for food research work.

ENGINEERING SERVICE for the FOOD INDUSTRIES

AS part of its service to the Food Industries during the past 50 years, Pfaudler has furnished not only the equipment for the process but frequently engineered the complete job. As a result of this experience in numerous branches of the industry, Pfaudler now offers a complete engineering service.

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ENGINEERS AND FABRICATORS OF FOOD PROCESSING EQUIPMENT

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The Student and Future Military Considerations

In these uncertain times the danger of a sudden emergency (War) is sufficiently great that all possible preparations should be made, including that of feeding a large and quickly assembled military personnel. As Colonel McKenzie has pointed out recently in the Quartermaster Review a fairly large reservoir of experienced Quartermaster officers is available at present; but time, death, and illness are taking their toll and many former officers are unable to continue Reserve Officer training. There is a growing need for younger men trained in the basic essentials in college and who also have Quartermaster training and industrial food technology experience. How can this need be met?

For one thing food technology instructors should indicate to promising upper division students the opportunities in the Reserve Corps and in active service in the food branch of the Quartermaster Corps. Perhaps a representative planning and liaison committee made up of Army, Navy, and Air Corps officers and University food technology professors would be very useful in planning and facilitating the training of young food technology students and graduates for this field. At present it is on a more or less hit or miss basis. Such a committee also could do much to secure assignment of food technologists to units concerned with food rather than to laundry, graves registration, or truck maintenance units, in case of War.

In some Universities are stationed Quartermaster officers who participate in R. O. T. C. training. These officers are available for consultation by food technology students, and no doubt would be glad to give several lectures on the Quartermaster Corps in established courses or might even give a lecture course of one or two terms in this subject. Heads of college food technology departments should take advantage of the presence of these officers on their university staffs. In some University communities, such as Oakland, California, Chicago, Philadelphia, New York, and Kansas City, are Quartermaster Depots or offices, whose officers would probably cooperate with food technology departments.

As to the undergraduate training in universities and colleges of prospective, future QM officers the same considerations apply as in the training of men for the food industries. As stated by Edwards (quotation in a recent Food Technology editorial by C. O. Ball): "The great end of education is to discipline rather than furnish the mind; to train it to use its own powers rather than to fill it with the accumulations of others." In other words the student should get thorough, sound instruction in the basic sciences of chemistry, physics, human nutrition, mathematics, and microbiology. In addition, he should obtain enough engineering to enable him to understand the engineer's language and to supervise processing operations, enough economics, accounting and business administration to give him a good basic understanding of military purchasing, accounting and administration, enough English and written expression to enable him to write clear, concise reports, specifications, etc., and enough psychology and human relations to help him to get along amicably with fellow officers, enlisted men and industrial men and to persuade superiors to accept his recommendations. If it can possibly be arranged there should be a QM R. O. T. C. unit at all colleges and universities that require R. O. T. C. training of their undergraduates for those who favor that branch of the service.

While basic college training is necessary, he should also get as much practical experience as possible as an undergraduate by working in food processing plants during vacations. As opportunity affords he should also get as much practical training and experience with QM units as possible in his graduate status. A fifth year, including both college and Army training, is very desirable.

Finally, the prospective officer will plan to join either the Officers Reserve and continue military training as opportunity permits or try to obtain a commission in the QMC as a career. He should be a member of the Institute of Food Technologists and of the professional society of his specialty—the American Chemical Society, Society of American Bacteriologists, or other society. Also, he should subscribe for and read the best of the food journals in order to keep up with current advances in food technology.

All of which "sounds like a big order"; in fact it is such, and cannot be completed in a mere four years of college; but the latter is the basic foundation on which a career must be built.

W. V. Cruess
President, I. F. T., 1943-44.

Notes and Letters

"FRESH COCKLES!"

Well, there she is again! "Notes and Letters," and there have been no letters. A section like this cannot live by notes alone.

Certainly there is an articulate readership that has opinions to air and exchange, which should find this section well suited to their wishes. A moment's reflection indicates that perhaps we have failed to "Call our Wares." For the benefit of those who have something that should be said, a novel view, or just a whimsical slant on matters of interest to food technologists:

Space Available!

Notes and Letters solicits your views!
This is the "Defend-to-the-Death-
-Your-Right-to-Say-It" Department.
Small orders given the same discriminating attention
as the Long Hair Stuff in the other sections.

Here is a specific suggestion. Write us at once about the following:

FOOD TECHNOLOGY is faced with the problem of cutting costs until the volume of advertising will have been increased. Suggestions under consideration for bringing about a reduction in number of editorial pages include the following:

1. **Elimination of Section Notes; their publication, if continued, to be in mimeographed form.**
2. **Elimination of the Abstracts since there are other good abstract sources.**
3. **Reduction in space given to editorial comment, although generally it is believed that some editorial comment should be retained.**

FOOD TECHNOLOGY readers are asked to let us know at once where they would like to see the "clipping" done if it has to be done. Let us know what you want. Don't wait until after a change has been made and then tell us that we made a mistake.

Let us hear from you.

N. AND L. EDITOR.

What Research Means to the Frozen Food Industry

(Condensed)

There exists an extraordinarily fertile opportunity to apply research in the frozen food industry. The research problems which must be tackled are derived from the following functions in which the frozen food processor finds himself involved:

1. Experience in industrial processing of food.
2. A good comprehension of the food to be prepared.
3. Enough capital to buy good equipment and first class raw materials, as well as financing for the early experimental and pilot plant stages.
4. A keen investigative understanding of the prospective market, and knowledge as to the best methods of merchandising.
5. Studies in freezing and storing the food to be prepared in order to know the changes in nutrient content, color, flavor and texture brought about by processing and storage conditions. If such information is available, the frozen food processor should be in a position to make or break himself — depending entirely upon whether or not he applies such research fundamentals.

I. Processing

Two important overall considerations which must be primarily acknowledged in the application of freezing methods are (1) enzyme action, and (2) rate of freezing. The only way to stop enzyme action completely is by heat or chemical treatment. The latter has its disadvantages because of certain restrictions laid down by food regulations. Heat treatment, i.e., "blanching" should be maintained at the lowest possible temperature and for the shortest possible time. Correct blanching time and temperature are usually different for each product, and sometimes even for different varieties of the same product.

A. *Slow Freezing.* The liquid portion or juice forming the major portion of most foods, and containing in dissolved form many minerals, color, flavor and nutritional substances, freezes out only pure crystals of ice. As more and more water is removed in this manner, the solution becomes increasingly concentrated and the solids start to crystallize or precipitate. The result is a mixture of rather large ice crystals with other solids suspended in a small residue of higher concentrated juice. Growing ice crystals break cell walls and, after thawing, part of the liquid content of the cells leak out. The food, therefore, has undergone both physical and chemical changes in appearance, flavor, structure and color.

B. *Quick Freezing.* Here the cell juice is cooled about 30° F. below the freezing point of water without crystallization (supercooling). At a certain point, it solidifies almost instantly, forming a matrix which contains all of the solids and color suspended in their original proportions. The cell walls are stretched, but few are broken, and upon defrosting the juice returns to its original composition. There is hardly any leaking and thus the material is very similar to the fresh product. In many products, freezing weakens the texture so that the cell walls sometimes collapse after defrosting. If the foods are eaten or cooked immediately after defrosting, this weakened structure problem is almost of no consequence.

Quick freezing may be accomplished by:

1. Sharp or still freezing where the packaged material is placed in a refrigerated room at 0° to —15° F. until frozen.
2. Air-blast, where air of high velocity at —10 to —30° F is circulated about the product.
3. Tunnel, similar to air-blast, except that the product is passed through a tunnel in a direction opposite to a blast of sub-zero air (—30° F.).
4. Single contact, where the product is placed on a metal plate or pan cooled beneath by circulating refrigerant at sub-zero temperatures.
5. Double contact, the best known example of which is the Multiplate Freezer. Here the food is contacted by two refrigerated plates.
6. Spray or fog freezing. Freezing is performed either before or after packaging by spraying very cold brine or sugar solution over the product.
7. Immersion freezing. Here the unpacked product is immersed in an agitated sirup solution at sub-zero temperatures. Excess sirup is removed by subsequent centrifuging.

During World War II the Germans froze bulk or packaged goods (chiefly fruits and vegetables) at Hochst, by covering with liquid nitrous oxide at —137° F. The gas was recovered and reused. While this pilot plant did not prove financially successful in the limited time it was used, it did prove that volatile liquid freezing had several advantages over most of the known methods, particularly the value of maintaining an inert atmosphere wherever possible.

More complete knowledge of the *heat capacity* of foods is an essential in selecting the most economical, yet effective freezing method for each product. This type of information is required for the more modern developments in electronic blanching and defrosting procedures. There are already on the market electronic defrosters of merit.

C. *The Problem of Water.* Of all the problems encountered in food freezing, water presents the most trying source of experimental evaluation. Many research workers are now occupied with the study of water in foods and modifications of the natural percentages found, and the subsequent effect on the final product. The writer has devised a series of experiments in an attempt to off-set the effect of ice expansion on damaging of tissue cells, which occurs to some extent even when fairly good quick-freezing techniques are employed.

II. Process Evaluation

Even when the correct process has been acquired, the packer and manufacturer must be able to evaluate a successful operation to appreciate what they have uncovered. Such process evaluation is usually based upon the application of nutritional chemistry and bacteriology to each step of the over-all procedure. The supplementary methods of organoleptic investigations finally determine the product's value.

From studies along these lines it has been possible to observe that frozen foods with too high mineral content, possibly due in part to brine processing, contribute to final toughness. The fact that freezing of crabs and lobsters has not been entirely satisfactory may be explained via the amino acid studies. Faulty freezing processes may actually bring about a dehydration which permits protein substances to combine or coagulate to form tough fibrous products within the food.

Products not recommended for freezing, based on lack of process control and current taste preferences are:

A. *Vegetables:* Cantaloupes, celery, cress, cucumbers, endive, lettuce, green onions, parsley, radishes, green peppers, sliced tomatoes and watermelon. Artichokes, cabbages, herbs, onions, hot peppers, white potatoes, pumpkins and rutabagas.

B. *Fruits:* Pears, bunch grapes, pomegranates, clingstone peaches (these may be frozen but are not as good as the freestone).

C. *Juices:* It does not seem advisable as yet to freeze-preserve vegetable juices other than tomatoes and rhubarb.

D. *Dairy Products:* For example, when cheese is frozen and then thawed, it tends to dry out rapidly and become coarse and crumbly. Recent methods are being developed to overcome this problem.

E. *Shell Eggs:* The shells invariably crack and the contents become thick and gummy when thawed. Shelled eggs can be readily frozen and provide a good product when defrosted.

F. *Meats:* The only deterrent to freezing of certain meats is that they may be cheap cuts and glands. These meats do not provide satisfactory food material.

G. *Fish:* In spite of the almost immediate initiation of spoilage, fish can be kept almost in as good a condition as fresh for many months provided they are frozen in the fresh condition as rapidly as possible and are maintained at —15° F.

H. *Precooks:* Precooked, frozen foods have made great advances within recent years. The preparation of this class of frozen foods involves far more extensive precautions than processes which are based upon fresh foods.

III. Financing and Equipment

The frozen food industry has, in recent years, flourished much beyond what might be considered a normal growth. Working capital requirements are considerable and equipment demand is very specific so that experience in related fields rarely serves the manufacturer to any extent other than to show him the need for specialized applications. The freezing process is currently the most profitable, but also the most costly method of preserving our highest grade foods. Unless adequately staffed by competent technical personnel, a man entering the frozen food field stands to lose his entire investment. The early experimental stages of investigation and the pilot plant stages must always be carried out prior to the actual production-scale processing.

IV. Merchandising and Marketing

A. *Packaging:* A survey of present packaging materials will show instantly that many attendant problems exist. For example, the fiber package with metal ends frequently exhibits bad clinch seals between metal and fiber. Tin cans are subject to a public health hazard, as are other opaque containers because the consumer can not tell if the food has been permitted to thaw out—and thus develop bacteria and other undesirable factors,—then refrozen prior to sale.

In the glass container, transparency is not always afforded the consumer due to the frosted surfaces. Also, the glass container fractures readily on rapid defrosting and rough handling. One of the best preservative containers for frozen foods to-date is the aluminum package, even though it possesses the objection of opacity.

B. Consumer education apparently does not pertain to any particular channel of study, other than that required to move a given product. At present the frozen food industry is faced with the peculiar situation of production being ahead of sales. To empty the warehouses by creating high demand, it is necessary to educate the consuming public in order to promote a frozen food consciousness based on superior acceptance value. High prices placed on frozen foods represent a barrier even when these foods are first-grade products. Price research must, therefore, be carried out to show what the consumer is willing to pay. Any sales which frozen foods hope to attain must be based upon inroads made into already garnered markets. It is, therefore, impossible for frozen foods to hold a market demand when the claim is made that they are just as good as fresh and canned foods. They must be better or cease to exist.

H. W. Dorn
Irvin, Neisler and Company
Decatur, Illinois

Precautions for Methyl Bromide Fumigations

(Condensed)

Introduction

Fumigation with methyl bromide, as with other gases, must always be conducted with certain precautions to avoid personal injury to fumigant operators.

There is no guarantee of absolute safety, but observance of the following suggestions will minimize the dangers and practical hazards of releasing methyl bromide in and aerating a building after fumigation.

Gas Masks

A gas mask (including the face piece, canister and harness) approved for this purpose by the U. S. Bureau of Mines should always be worn properly, and with a full understanding of its limitations at any time it is necessary to enter an atmosphere that may contain methyl bromide.

The mask should be checked for leaks before it is used. This is accomplished by putting on the mask with canister attached, placing the hand over the hole in the canister and inhaling. If perfectly tight the face mask will collapse.

When methyl bromide is the only gas to be encountered a *black canister* for *organic vapors* should be used. If the presence of other types of gases requires the use of the *yellow canister* or the *red all purpose canister*, protection against methyl bromide is given, but for a shorter time than with the *black canister*.

The Bureau of Mines approved black canister, face piece, and harness is designed to afford protection in air having up to 2% by volume of methyl bromide. A 2% concentration is equivalent to 5 lbs. of methyl bromide per 1000 cu. ft. of space. The length of time a canister affords protection depends upon these factors:

1. Type of canister.
2. Concentration of gas breathed.
3. Rate of breathing (Total quantity breathed).

Based on the concentrations employed in good fumigation practice employing methyl bromide or methyl bromide containing 2% chloropicrin, and a high rate of breathing, the following tabulation of "Maximum Time Canisters Should be Used" may be applied. If other gases are present these periods of time may be shorter.

Suggested Maximum Time Canisters Should be used in Methyl Bromide Fumigations

Type of Canister	Concentration of Methyl Bromide in lbs. per 1000 cu. ft.			
	1 lb. or less	1 to 2 lbs.	2 to 3 lbs.	3 to 4 lbs.
	min.	*min.*	*min.*	*min.*
Supersize Black (For organic vapors)	120	60	45	30
Regular Size Black (For organic vapors)	60	30	22	15
Supersize Yellow (For acid gases and organic vapors)	30	20	10	5
Regular Size Yellow[a] (For acid gases and organic vapors)	18	13	10	5
Red (All purpose)	18	13	10	5

[a] At present no regular size yellow canisters are approved by the U. S. Bureau of Mines.

Always use a fresh canister when releasing the gas in a space fumigation. Always use a fresh canister when starting to aerate a building.

Always replace canisters according to the above schedule, both during release of gas and during aeration. It is recognized that much of the gas will have escaped during the period of exposure but one cannot tell how much is left at the time the building is opened without checking with a Halide Gas Detector. Evidence indicates there is frequently enough gas left to be harmful if breathed for as short a time as 30 minutes. If the Halide Gas Detector shows no blue color, only green, your canister should give adequate protection for twice as long as indicated for a concentration of 1 lb. per 1000 cu. ft.

Detection of Methyl Bromide Gas

The Halide Gas Detector (known commercially as the Prest-O-Lite Halide Leak Detector) which operates with an acetylene gas flame is the easiest and most useful means of determining the presence or absence of harmful concentrations of methyl bromide gas. The detector consists of an acetylene torch which heats a copper cone, and an air tube through which the air to be tested is passed over the hot copper. In air containing methyl bromide a green or blue flame will be seen in the torch depending on the concentration. The following tabulation gives the approximate methyl bromide concentration associated with color intensity in the flame:

Methyl Bromide Present Parts per Million	Pounds per 1000 cu. ft.	Flame Color in Daylight[b]
0	0	No color
25	0.00625	Faint fringe of green
50	0.0125	Moderate green
125	0.031	Green
250	0.0625	Strong green
500	0.125	Strong green—blue fringe
800	0.20	Strong blue—green
1000	0.25	Blue

[b] Note that in using the gas detector at night the flame has a bluish cast which has to be taken under consideration, otherwise the color changes are the same.

Use the Halide Gas Detector:

1. After releasing the gas, check from the outside the first floor and basement doors, windows and other openings for excessive leakage. Seal any leaks found to be excessive.

2. Check concentration of gas when starting to aerate the building. This serves a two-fold purpose: It indicates the approximate amount of gas the operators will be in during aeration. It will also give an indication of the leakage of the building during exposure. This information is helpful in determining the dosage to use in future fumigations of the building.

3. During aeration, rest periods should be taken by the operators. Although these rest stations should be a considerable distance from the building under fumigation and in an area free from gas, it is always advisable

to check with the gas detector to be sure no gas is present.

4. Use the gas detector to determine when the building is completely aerated and safe to be turned back to the owner for re-entry by the workmen.

Releasing Methyl Bromide

Every space fumigation regardless of how large or small should be well planned ahead of time by the fumigator. This plan should include such things as size and placement of cylinders, fans, route to follow in releasing gas and method of turning off the fans. The route, when possible, should be so arranged that, starting on the top floor, the operators can open the valves on the cylinders, walk away from the gas being released, down the stairway to the next floor. This same procedure should be followed on each succeeding floor.

It is recommended that at the time the caps are removed from the cylinders the valves be cracked (sometimes referred to as splitting the cylinders), in order to be sure the cylinders will open properly and not cause any undue delay during the actual release.

It is advisable to rehearse the routes to be taken by the operators prior to the release of the gas. This serves to familiarize the operators with their routes and will allow the head operator to check the time necessary for the actual release. The routes should be planned so as to complete the operation in the shortest time possible.

Under no conditions should the operators be in the building longer than 30 minutes in releasing the gas. If it is impossible for one crew of two operators to release the gas in 30 minutes, additional experienced crews should be used.

As a matter of good fumigation practice, two men wearing gas masks should always work together when the gas is released. These men should always remain close to each other, from the time they open the first cylinder until they leave the building through the exit door.

Aerating the Building

At the end of the exposure period *most buildings will contain a considerable amount of gas.* The amount of gas remaining in the building at this time will depend on several factors such as: original dosage, type of building, type of sealing, length of exposure and weather conditions during exposure. A quick check with the gas detector will indicate the approximate concentration of gas remaining in the building which should play an important part in the plans for aeration. The important thing is to get a few windows or doors open on opposite sides of the building on each floor to allow for cross ventilation. Start the aeration by opening all of the doors on the first floor from the outside. Allow the building to stand in this condition until the gas detector fails to show a blue color. The circulating fans should be started as soon as possible and allowed to run during the aeration period. *Do not try to open all the windows on each floor the first time through.* Two men equipped with gas masks and *fresh* canisters should work together during the aeration as well as in releasing the gas. The operators should take rest periods in the open air free from any gas after opening each floor. After a few windows have been opened on each floor, the building should be allowed to aerate for one hour or longer. At the end of this aeration period, the gas detector will indicate which floors require additional ventilation.

Emergency Care

There is no need for exposure of individuals to appreciable concentrations of methyl bromide in proper fumigation procedures. Under accidental conditions, however, such exposure may occur. Following are possible symptoms of methyl bromide exposure:

1. Nausea
2. Dizziness
3. Staggering gait
4. Blurring of vision
5. Slurring of speech

At the first sign of *any* of the above symptoms, *immediately* get out of the gas into the fresh air. It is advisable for a crew of men on a fumigation job, working under the same conditions, to stop immediately if one of their members becomes sick. This is based on the possibility that if one man is getting gas, they all are. *The affected operator should be taken to a physician, or a physician called immediately. Under no conditions should he re-enter a methyl bromide atmosphere until he has received the approval of a physician. Since there is a possibility that the other members of the crew have also been unnecessarily exposed to the gas, they too should refrain from re-entering the building. Another experienced crew should be called to complete the aeration.*

Manufacturers of Gas Mask Equipment

The U. S. Department of Interior, Bureau of Mines, Health and Safety Branch, 4800 Forbes Street, Pittsburgh, Pa., gives the following list of companies manufacturing approved gas mask equipment which include the black organic vapor canister. This represents approvals as of June, 1948.

Acme Protection Equipment Company
33-35 West Lake Street
Chicago, Illinois

E. D. Bullard Company
275 Eighth Street
San Francisco, California

Davis Emergency Equipment Company
45 Hallack Street
Newark, New Jersey

Mine Safety Appliance Company
Braddock, Thomas and Mead Streets
Pittsburgh, Pa.

Wilson Products, Inc.
Reading, Pa.

F. W. Fletcher
The Dow Chemical Company
Midland, Michigan

Process Evaluation

Comment on Stumbo's "Bacteriological Considerations Relating to Process Evaluation," followed by an outline of an improved procedure for calculating sterilizing processes.

* * * *

In the April, 1948 issue of FOOD TECHNOLOGY was published a fine presentation of "Bacteriological Considerations Relating to Process Evaluation" by C. R. Stumbo. After a study of this paper, I disagreed with Dr. Stumbo on his concept of the "probability of survival" among bacteria which are uniformly distributed within a mass of food. It seemed to me that each unit volume of the food substance was being regarded in a different light than every other unit volume, and that this fact was then disregarded in applying a rate of destruction, or survivor, curve simultaneously to units of volume of different magnitudes, in calculating the "probability of survival" in different regions within a container. In this issue (April, 1949), is another paper by Dr. Stumbo, entitled "Further Considerations Relating to the Evaluation of Thermal Processes for Canned Food." Therein, the same concept of "probability of survival" is further discussed.

The rate of destruction, or survivor, curve tells us that the bacterial spores in each unit volume, on the average, are affected to an equal extent by a given quantity of lethal heat. Our reasoning has been that, since this is a fact, bacterial spores are most likely to survive in the unit volume which receives the smallest amount of lethal heat. This unit volume is located either at the center of the container or a short distance below the center, depending upon the nature of the product. Process calculation procedures have been based upon this principle.

The concept that the greatest probability of survival of spores does not necessarily exist in the region that receives the least lethal heat, as presented by Stumbo, appeared to have logical aspects but it seemed to me that his explanation lacked a point which would enable me to perceive a logical relationship between this concept and the idea that has been generally accepted that the spores in the unit volume which receives the least amount of lethal heat are the ones which are the most likely to survive and cause spoilage. Exasperated by my failure to see clearly why either this viewpoint or Stumbo's viewpoint is incorrect, I continued to study the question. I believe now that I have discovered the source of my difficulty and, thinking that my solution might be helpful to some other investigator who is striving to achieve a clear line of thinking on this problem, I decided to try to tell the why of my difficulty.

The trouble lay in the fact that I was unable to answer to my own satisfaction the question: With respect to what thing may the phenomenon which was revealed by Stumbo be designated "probability of survival"? Obviously, it could not be so designated with respect to the unit volume of material but, considering the meaning of the word "probability," any other relationship seemed illogical. Mental grasping of the new viewpoint was hindered also by difficulty in casting aside the idea that sterilization of food by heat is concerned only with complete destruction of spores. Notwithstanding the fact that I myself had presented, in a paper[a] in 1943, the idea that we must think along other lines, my failure to carry this reasoning to a conclusion caused me to continue to think, without realizing that I was doing so, along the old line to such an extent that the correlation of the old idea with the new was obscure to me.

If all of our sterilizing processes could be carried to the point of complete destruction of spores, our old concept would apply without modification. It cannot apply, however, when we concern ourselves with any instant prior to the instant of complete destruction. Since complete destruction, theoretically, is never assured, we are necessarily concerned with incomplete destruction. Certainly, when we think about spoilage due to a failure to carry a process to the point required for sterilization, we must think about the question of where are the surviving spores which cause the spoilage. The troublesome obscurity faded quickly when I set aside the designation "probability of survival" and substituted for it the designation "distribution of survivors."

The line of reasoning which brought to me a clear perception of the relationship existing between the new concept and the accepted percent survival-time-temperature relationship is as follows:

It is true that the average reduction in number of viable spores per unit volume (say 0.1 ml[3]) is in accordance with the rate of destruction, or survivor, curve, but, as Stumbo stated, the likelihood of spoilage probably depends upon the total number of survivors within the container, not on the number per unit volume. The total number is the average number per unit volume times the number of unit volumes.

The crux of the situation with which we are concerned lies in the fact that the meaning of "probability" forbids the use of the word in the sense in which Dr. Stumbo has used it. The word has meaning only when used in comparing conditions in terms of a basic entity which has constant value. In the present case, the basic entity must be volume, not regions or layers. The basic entity in this problem, as in other problems, must be uniform in value; it must be a constant unit volume, otherwise the word "probability" may not be used.

If all unit volumes obtained the same heat treatment, the average number of survivors per unit volume would be as indicated by the survivor curve, applied to the given unit volume, for that heat treatment. When different unit volumes are subjected to different heat treatments, the average number of survivors in all unit volumes which are subjected to a given heat treatment is that shown by the survivor curve, applied to the given unit volume, for that heat treatment.

There are groups of unit volumes, each of which groups comprises a layer of which all parts receive lethal heat to give the same F-value. Each such group may be called an "iso-F-value group." According to Stumbo's definition, the iso-F-value group which, in the aggregate, contains the greatest number of surviving spores at a given instant in a process is the group in which the

[a] Short-time Pasteurization of Milk, *Ind. Eng. Chem.* **35**, 71 (1943).

spores have the greatest "probability of survival." I prefer to designate this iso-*F*-value group of unit volumes as the group which contributes more than any other iso-*F*-value group toward the probability of spoilage, due to under-sterilization, occurring in the product. Its contribution is measured by multiplying the number of unit volumes in the layer by the average number of survivors per unit volume in the layer. This, as I understand it, is Stumbo's hypothesis. His computations give the weight of this contribution to the probability of spoilage.

To illustrate this principle, let us assume that there is one unit volume in the location which receives the least amount of lethal heat and that the *F*-value attained there is *d* minutes. Let us assume that an iso-*F*-value region of "greatest probability of survival," according to Stumbo's interpretation, can be shown to exist. Let us assume also that the iso-*F*-value region of "greatest probabilityof survival" is a region containing thirty unit volumes comprising a layer of material in the shape of an enclosed cylinder which we will say is one mm. thick in the cylindrical wall and of either the same or a different thickness in the ends, located a given distance from the center of the unit volume having *F*-value, *d* minutes, and that in this region of "greatest probability of survival," an *F*-value of *2d* minutes is attained during the given process.

During the time in which the number of spores in the first unit volume is being reduced to one, let us assume that the number of spores in the other thirty unit volumes is being reduced to an average of 0.3 spore per unit volume. At this instant, the first unit volume contributes one spore while the other thirty unit volumes contribute 0.3 times 30, or nine spores, to the supply of survivors which may spoil the food.

Notwithstanding the fact that the thirty unit volumes having an *F*-value of *2d* minutes contributes nine times as many survivors to the supply in the container as a single unit volume having an *F*-value of *d* minutes, we find that it is still true that these thirty unit volumes do not contain as many survivors as any equal volume (thirty unit volumes) of material lying within the layer which comprises the region of "greatest probability of survival." By the same token, this group of thirty unit volumes, having *F*-value of *2d* minutes, contains more survivors than any equal volume (thirty unit volumes) of material lying outside of this region of "greatest probability of survival." Thus, it is important that we keep in mind the fact that, although the iso-*F*-value region having the "greatest probability of survival" does contain more survivors than any other iso-*F*-value region which meets Stumbo's definition of such regions, the former region does not contribute as heavily to the probability of spoilage as does any combination of such regions lying within the former region in the container and containing a volume of material equal to that of the region of "greatest probability of survival." As stated previously, this comparison, to qualify for the use of the word "probability," must be made in terms of a uniform volume of food.

We may explain this example further by saying that the fact that the probability of survival is nine spores in thirty ml³ in one location and is one spore in one ml³ in another location in the container does not indicate that the probability of survival is greater in the former location than in the latter. Such a conclusion would be contrary to the definition of probability. We may correctly say that the probability that there will be nine survivors in thirty ml³ in the first location is the same as the probability that there will be one survivor in one ml³ in the second location. In other words, the probability that there will be one survivor in one unit volume in the first location is the same as the probability that there will be 0.3 survivor per unit volume in the second location. The only thing which a consideration on the basis of imaginary layers does in respect to probability is to help to show why the probability is what it is.

When Stumbo's concept is explained in these terms and when the limitations of the old concept are recognized, it seems to me that the old and the new ideas are in perfect harmony. In establishing processes in the light of the new ideas, the rate of heating in the location receiving the smallest amount of lethal heat can still be used for the purpose of determining the total number of surviving spores in the container, giving a result which is identical to that obtained by using Stumbo's method of calculating on the basis of iso-*F*-value layers. The calculation of a sterilizing process would not, as in the past, be based upon the region which receives the smallest amount of lethal heat nor would it be based, as Stumbo suggests, upon another region which he designates as that in which there is the "greatest probability of survival" of a spore. Instead, it would be based upon the total number of surviving spores in the container. The data required for this calculation would be (1) a heating rate curve for the point which receives the smallest amount of lethal heat, as in the past, and (2) a system of rate of destruction, or survivor, curves for at least four different temperatures. I visualize such a calculation as consisting of the following three steps:

1. From one of the rate of destruction, or survivor, curves (preferably, but not necessarily, the curve representing the processing temperature being considered), find the time-temperature combination corresponding to a reduction from the *total number of spores in a container* to 1×10^{-9} spore.[b]

2. From a phantom thermal death time curve, established from the rate of destruction data, find the *F*-value corresponding to the time-temperature combination found in step 1.

3. From the heating rate curve for the container, find the time necessary to attain an average *F*-value for the container equal to the *F*-value found in step 2. This will be the calculated process.

The paper, "Evaluation of the Effects of Heat Processing Upon the Organoleptic Quality of Canned Foods," by Ball, Olson, and Boyd, which the writer presented on June 8th, 1948, at the Philadelphia meeting of the Institute of Food Technologists, and which will be published as soon as necessary extensive tables of parametric values have been completed, puts this method of calculation into workable form. Therein it is applied to vitamins, however, instead of to bacterial

[b] This figure is arbitrarily chosen; some value either greater or less than 1×10^{-9} may be chosen to indicate the number of surviving spores per container.

spores. It shows the calculation of average destruction in the container at any given instant. The method applies equally well to bacterial spores and to vitamins. It uses the method outlined above for determining average F-value within a container.

The above discussion may add enough to Stumbo's explanation of the principles involved in his concept to make his reasoning clear to some who experienced a difficulty similar to mine.

C. Olin Ball.

A Note on the Nature of a Flavor Constituent from Poultry Meat

In a recent review by E. C. Crocker (1948), the flavor of meat is discussed in two parts: the flavor of raw meat and its juices, and the flavor of cooked meat and fibre. Crocker indicates that meat flavor is an odoriferous compound associated with the cooking process. In other words, the flavor of meat is either a breakdown product of meat or is only released from the meat on cooking. In the same paper Crocker described an experiment carried on in his laboratory whereby the gases were collected from meat while cooking. He identified the flavors as hydrogen sulfide and an unknown volatile acidic compound.

Bate-Smith (1948) in his work on pH in relation to fasting animals has shown the effect of ingestion of food on the pH of meat. Fasted animals have sometimes as much as 2 pH units difference in reaction. The normal animal has a tissue pH of about 5.8 while the fasted animal has a pH of 6.8 to 6.9.

The effect of fast on pH of tissue is easily demonstrated in chickens. However, the fasted chicken is more acid than the fasted mammal. The chicken under fast has a pH of 6.4 while the mammal has a pH of 6.8.

Since the method of feeding and the length of the fast had such a great effect on the pH of the tissue it seemed proper to study the effect of pH on the flavor of chickens.

Experiment:

An eviscerated, young Leghorn cockerel was ground and the meat uniformly mixed. Ten gram samples of the flesh were weighed out, and blended with 100 cc. of phosphate buffer in a Waring Blendor. The mixture was immediately boiled and the flavor evolution from each sample graded. The odors were identified as closely as possible.

Results such as these indicated that meat flavor and chicken flavor might well be, as Crocker had suggested, due to some acidic compound. Indications were that the compound was non-volatile under basic conditions.

In an experiment on dialysis of chicken flesh another character of chicken meat flavor was observed.

Chicken meat was finely ground and homogenized. It was placed in cellophane dialyzing membranes and dialyzed against distilled water at 0° C. After warming to room temperature the dialysate was rich in chicken flavor. Further purification and concentration of the material was accomplished by use of Duolite A-3 and C-3 ion exchange columns. Upon testing the fractions from the columns it was found that the flavor had absorbed into the anion column, and could be eluted with dilute sodium hydroxide. Upon neutralization of this eluate a strong essence of chicken evolved. The flavor constituent could be further purified by steam distillation. Care had to be taken in this procedure, for though the flavor distilled, it could not be condensed in the presence of the carbonic acid from the eluate. This carbon dioxide was formed in the ion-exchange eluate when the sodium hydroxide was neutralized. It had been fixed in the form of sodium carbonate during the ion-exchange procedure.

*Table showing the change of flavor as pH of the meat changed**

pH	Flavor
Strongly acid (pH 1 to 4)	Strong chicken flavor which completely distills in a few minutes.
5.8	Strong chicken which persists in the broth.
6.2	Mild chicken, with a flavor described by tasters as "meaty."
6.8	"Meaty" flavor more pronounced with a very slight odor of chicken.
7.0	Flavor very weak, described as only "meaty."
7.2	Flavorless.
7.6	Detectable odor described as "basic"; a slight odor of piperdine was noted in some cases.
8.0	Sulfury odor predominates; odor described by tasters as "boiled egg" flavor.
Strongly basic (pH 9 and above)	Ammonia and other volatile amines predominate to the exclusion of other odors.

* As graded by a group of subjects on a number of occasions.

As the study of the flavor constituent progressed it became evident that the removal of flavor from tissue necessitated some sort of drastic treatment of the flesh. This treatment may be heat, or any chemical method available for protein denaturation. The methods tried with success were homogenization with alcohol, saturated urea, and trichloracetic acid. Fatty acid and amino acid content of the dialysate from the original proved exceedingly high, indicating enzymic digestion had taken place.

Summary

A flavor constituent from chicken meat has been isolated and partially characterized as to its properties. It appears to be a weak acid, produced in the flesh during cooking. The compound is easily dialyzable, and can be concentrated on the anion column of an ion exchange operation. The flavor can be further purified by steam distillation.

REFERENCES

Bate-Smith, E. C. Observations on the pH and related properties of meat. *J. Soc. Chem. Ind.*, **67**, 83 (1948).

Crocker, E. C., Flavor of meat. *Food Research*, 13, 179 (1948).

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Ascorbic Acid and Color in Food Products[a]

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The application of ascorbic acid to the preservation of color in food products is described as a result of many years' work by the author. When used as an antioxidant for fish, successful retardation of rancidity is reported. Some of the other foods advantageously treated are: peaches, apples, berries, citrus fruits, juices, purees and wine. This paper is based on work and results performed by the author.

Color retention is extremely important in maintaining the sales appeal of many food products. Ascorbic acid has become an important chemical for many frozen, canned and other foods, for preserving their natural color. Ascorbic acid may be used with the assurance that the flavor is not impaired, in addition to improving the product's nutritive value.

Ascorbic acid was first used for preventing browning of peaches in the freezing, frozen and thawed state. This problem was so serious that freezing of peaches dwindled to a very low figure. Since its use, frozen peaches have become a very important product of commerce. Many different materials are reported in the literature as aiding in the prevention of browning of fruits. However, very few of these materials have ever been utilized commercially because of one reason or another. They affect either the flavor, the texture, or are not permitted by food laws. Some of these materials are glutathione or cystine salts, thiosulfate solution, thioamide compounds, caramelized milk solids, sodium bisulfite solutions, 0.1 percent thiourea, 20 percent pineapple juice, 5 percent sodium chloride, and acids such as 1 percent sulfurous acid, 0.1 percent hydrochloric acid, 2 percent citric acid, tartaric acid and lecithin, tocopherols and oat extracts.

There are objections to most of these products' being used. The Federal Food and Drug Administration does not permit the use of thiourea. Sodium chloride is not practical because of its effect on palatability. Sulfurous acid is a reducing agent and tends to destroy the yellow color and gives an objectionable flavor to the product. Citric acid has been used after peeling, especially after peeling with lye to neutralize the lye and to retard browning for a short time until ready to slice. Even after holding peaches for a time in 2 percent citric acid, they will gradually turn brown. When citric acid is used in sirup packs in excess of 0.1 to 0.2 percent citric acid of the total weight of the fruit, the fruit becomes too tart. At this strength, the citric acid is ineffective in preventing discoloration in packed fruits. Lecithin and tocopherols are oil soluble and, therefore, are impractical to use in water solutions. Oat extracts are ineffective. In fact, they encourage browning.

General considerations in using ascorbic acid:

(1) Copper utensils should never be used where ascorbic acid is added to fruits if loss is to be prevented. Ascorbic acid stability in solutions is an important consideration.

(2) Under repeated tests, ascorbic acid loss has been found to be rapid in water solutions at room temperature even though the pH may be rather low, but the ascorbic acid is retained for long periods of time in medium to heavy sugar sirups (30 to 60 percent).

(3) Where lye peeling methods are used, the excess lye should be neutralized by using a fruit acid, 1 to 2 percent strength, e. g. citric or tartaric acid, before the ascorbic acid application.

(4) In a few instances, with peaches in particular, the addition of a very small amount of acid may enhance the flavor of the fruit, but the amount acceptable should not exceed 0.2 percent of the total weight of the fruit. Any one of the other food acids in this strength does not prevent browning. Ascorbic acid in the amounts of 0.03 to 0.05 percent will prevent discoloration when dissolved in the sirup to be added to the fruit in the ratio of 12 ounces fruit to 4 ounces sirup.

(5) The storage temperature for ascorbic-acid treated foods must be maintained at a low temperature of 0° F. (— 17.8° C.) or below.

(6) As much air as possible should be excluded from the package. This is rather easily done with small consumer packages where the air can be forced out before sealing, but it is quite a problem with cans and barrels. Proper filling aids considerably.

(7) Since the effectiveness of ascorbic acid is greatest on fruits packed in sirup, it is necessary to keep the fruit segments completely submerged. Some means of holding the fruit submerged, therefore, is desirable. A cardboard disc seems to be most practical with 30- and 50-lb. cans.

(8) When ascorbic acid is used, it must be declared and labelled to conform with the provisions of the Federal Food, Drug and Cosmetic Act.

Apples: The problem of preserving the color of fresh-cut and frozen apples is somewhat more difficult than that of peaches. Large quantities of peaches are sold retail whereas very few frozen apples are sold in this manner. Peaches packed in large containers and sold to bakeries are acceptable when packed in sirup. On the other hand, the trade will not accept apples packed in this manner. Since ascorbic acid is most effective when added to the sirup in packing fruits, it makes the problem much more difficult. Dipping apples to be used as fresh fruit in an ascorbic acid solution permits the holding of the apples for many hours without discoloration. However, dips for apples to be frozen are less effective in preserving color when defrosted. The application of ascorbic acid in sirup by vacuum method for a few varieties was partially successful, but as a general rule it is not recommended. The only method that is completely effective is the use of ascorbic acid together with inactivation of the enzymes by heating the apple slices at 180 to 185° F. (82 to 85° C.). Many apples at the present time are processed by blanching which consists of heating them for a short period in live steam or in

[a] Presented before the Eighth Annual I. F. T. Convention, Philadelphia, Pa., June 9, 1948.

TABLE 1

Ascorbic Acid Retention in Sirup at Room Temperature (70° F., 21° C.)

Treatment	Days held							
	0	3	6	7	12	13	15	17
	mg./ml.	*mg./ml.*	*mg./ml.*	*mg./ml.*	*mg./ml.*	*mg./ml.*	*mg./ml.*	*mg./ml.*
Ascorbic acid in water	3.8		2.1			0.14	0.12	
Ascorbic acid in 60% sirup	2.4		2.36			2.23	2.13	
Ascorbic acid in 30% sirup	2.25		2.12			1.70	1.47	
Ascorbic acid in 60% sirup with 0.1% calcium chloride	2.39	2.23		2.18	2.15			2.15
Ascorbic acid in 60% sirup with 0.1% calcium chloride and 0.05% sodium bisulfite	2.34	2.22		2.31	2.22			2.21

boiling water to inactivate the enzymes. This method renders many of the better varieties soft and mushy. Pie-makers object to this type of product. However, the same varieties, when heated at low temperatures 180 to 185° F. (82 to 85° C.) to inactivate the enzymes, do not become as soft, but they discolor rather seriously while heating through. Ascorbic acid is added to the blanching medium, thus preventing any discoloration. For the softer varieties of apples, e.g. Cortland and McIntosh, minute amounts of calcium chloride have been used as a firming agent in conjunction with the ascorbic acid, without any significant loss of the ascorbic acid if the medium is a sirup or a juice of from 30 to 50° Brix.

Analysis was made of losses of ascorbic acid from frozen apples packed with sirup, upon defrosting.

TABLE 2A

Effects of C. P. Citric Acid on Retention of Ascorbic Acid in Frozen Apples

Apples treated with:	Ascorbic acid present		
	Frozen	Defrosted 6 hrs.	% loss
	mg./g.	*mg./g.*	%
Ascorbic acid only	0.588	0.377	35.8
Ascorbic acid and citric acid	0.377	0.105	72.1

TABLE 2B

Effects of C. P. Citric Acid on Retention of Ascorbic Acid in Frozen Apples

Apples treated with:	Ascorbic acid present				
	After treatment	Defrosted 1 hr.	% loss	Defrosted 16 hrs.	% loss
	mg./g.	*mg./g.*	%	*mg./g.*	%
Ascorbic acid only	0.485	0.332	31.5	0.066	86.4
Ascorbic acid and 0.2% citric acid	0.464	0.372	20.0	0.014	96.9

Peaches: Ascorbic acid when mixed with the sirup and used at the rate of 150 to 200 mg. of ascorbic acid per pound of packed fruit has outstanding value in preserving the color and flavor. It is the most desirable method of any of the treatments for peaches, because it retards the browning without affecting the flavor, natural color or texture. However, in spite of these advantages, the use of ascorbic acid has disadvantages, thereby requiring careful and wise use for economical and effective results.

Berries: Some suggestions have been made for using ascorbic acid in frozen strawberries and raspberries to preserve color and flavor. Several years of testing and trying these products have indicated that ascorbic acid is valuable only in rare instances when the natural ascorbic acid has been oxidized by adverse storage conditions.

Citrus fruits: Although citrus fruits are recognized as relatively high in natural ascorbic acid, the addition of a small amount (150 to 200 mg. per pound of packed fruit) of ascorbic acid has been found to be beneficial in some instances in preserving the fresh flavor and reducing the bitterness which sometimes develops, particularly in frozen grapefruit.

Other products: There are some products that are not of great importance commercially but which can be treated effectively with ascorbic acid, enhancing their quality during handling as a fresh product or in defrosting. Potatoes are often peeled in central locations and then are held and transported some time later. The addition of ascorbic acid to the water (0.33 g. ascorbic acid per 1 gallon water) preserves the white color. *Purées* (avocado, peach, plum, sweet potato, apricot, asparagus): there are many purées of vegetables and fruits whose color is effectively preserved by the addition of 0.02 percent ascorbic acid to the purée. The ascorbic acid may be stirred into the purée after it is made. It is very effective if the ascorbic acid is added to the fruits as they pass into the finisher. Some oxidation of the ascorbic acid and some loss to the pomace occurs when it is added in this way.

Juices: Ascorbic acid is found to stabilize the color and flavor of bottled or canned apple juice. When it was first used, ascorbic acid was added to the apple juice in mixing vats or to the juice as it passed through metering devices into the bottles. Later, however, it was discovered that the ascorbic acid was more effective in retaining the color and flavor if it was added in a water or juice solution to the apples as they passed through the grinder or hammermill before any oxidation had taken place.

Grape juice develops a red sludge and gradually turns a dirty brown color when kept in the warehouse or when held on the grocery shelf. Ascorbic acid was investigated as a possible agent for preventing this change. The present work does not indicate that ascorbic acid is of any particular value in grape juice.

Wines: White wines such as Rhine, Tokay, white Sauterne and Reisling, require the addition of an agent if the color is to be retained during transportation, and trade. Sulfur dioxide, although it is the best chemical thus far, alters the flavor somewhat. Work has been carried out and it has been found that ascorbic acid (200 to 250 mg. per fifth of wine) preserves the wine color.

Fish: Generally, fish are difficult to freeze and store for any length of time without change in flavor of the flesh and without the development of rancidity in the fat. The changes in flavor are usually detected sooner in the fatty fish than in the so-called lean fish because the rancid taste of the fat develops in greater intensity than oxidative flavor changes in the flesh. The storage temperature has a considerable effect on the rate at which the changes occur. Thus, fish stored at 10° F. (— 12° C.) develop the off-flavors much more quickly than do fish treated in the same manner but stored at 0° F. (— 17.8° C.). Protection of the cut surfaces against desiccation by some method is a necessity. Aside from causing a dry condition of the fish, desiccation of the fish tissue accelerates rancidity and denaturation of the proteins. The surfaces' protection can be accomplished in two ways: (1) an ice coating or glaze and (2) packing or wrapping the fish in moisture-vapor-proof material. The glaze is used for large fish or pieces of fish difficult to package. Wrapping materials are used to package and protect fillets and steaks.

Sodium chloride added by dipping the fish in sea water or in salt baths accelerates the development of rancidity in fish fat. However, our preliminary studies indicate that where ascorbic acid was added to the fish in the medium of the salt bath the lean fish did not become rancid or develop the "salt, fishy" flavor. The greater the amount of cut surface, naturally the more subject the fish is to changes during storage. With the trend more toward filleting and steaking fish and then marketing them frozen, it is important that fish retain their fresh character during storage. Many fish are seasonal, and, therefore, the maintenance of quality from season to season is important. Ascorbic acid has been found by our work to be beneficial in retarding the oxidative changes in fatty fish such as mackerel and salmon as well as in lean fish such as rosefish and haddock. Untreated fish stored at 0° F. (— 17.8° C.) developed the "old salt, fishy" flavor in 6 to 8 months. By using an ascorbic acid dip at the rate of 0.1 to 0.5 percent for 30 to 60 seconds, the storage life of the fish was prolonged several months. The dip is usually added to the fresh cut fillets or steaks immediately before the wrapping procedure. Large whole fish, such as salmon, may be dipped in an ascorbic acid solution prior to being frozen or the frozen fish may be dipped in the ascorbic acid solution to produce a glaze. If the ascorbic acid is added as a glaze, an over-coating of ice helps protect the ascorbic acid. Other protective coatings to carry the ascorbic acid have been used.

When frozen and then defrosted, *oysters* often discolor enough to detract from their quality and appearance. The discoloration with some oysters is a grayish green and with others it is a light red. The addition of 0.2 percent ascorbic acid mixed well with the oysters has prevented this color change.

BIBLIOGRAPHY

1. Balls, A. K., and Hale, W. S. Peroxidase in the darkening of apples. *Ind. Eng. Chem.*, **27**, 335-7 (1935).
2. Colvin, D. L. Discoloration of peaches. *Mimeo. unpublished.* Louisiana State University. (1945).
3. Cruess, W. V. *Commercial Fruit and Vegetable Products.* 2nd Ed., 1938. McGraw-Hill Book Co., New York, N. Y.
4. Denny, Frank E. Inhibiting discoloration of cut surfaces such as those of apples. U. S. Pat. 2,093,865. (Sept. 21, 1935.)
5. DuBois, C. W., and Colvin, D. L. Loss of added vitamin C in the storage of frozen peaches. *Fruit Prod. J.*, **25**, (4), 101 (1945).
6. Tressler, D. K., and DuBois, C. W. No browning of cut fruits when treated by new process. *Food Ind.*, **16**, (9), 701 (1944).
7. Woodroof, J. G. How to prevent browning of peaches in the freezing industry. *Food Ind.* Part I, **15**, (5), 35 (1940). Part II, **15**, (6), 50 (1940).

Frozen Apples and Apple Products[a, b]

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A review of experimental work on methods of preventing darkening and oxidation in frozen sliced apples is presented. Methods for the preparation of an apple ice cream mix and frozen peeled apples with filled cores suitable for salad and dessert use are described.

Frozen apples have been well received and hold an important place among commercial frozen fruits. Most of the frozen apple pack consists of sliced apples destined for use in one of our favorite desserts—apple pie. It is important that apples for this purpose be processed in such a way as to maintain the good qualities of fresh pie apples. Such apples can provide the desirable attributes of flavor, color and texture that are associated with good apple pie.

The purpose of the present report is to review the general methods that have been used in freezing sliced apples and to point out certain procedures that can be employed to improve the quality of the finished product. Certain other frozen apple products are also discussed.

Freezing Sliced Apples

The general procedures followed in freezing sliced apples may be outlined as follows: the apples are washed, then peeled and sliced on one of several types of equipment available for this purpose. The sliced fruit may then be passed through a squirrel-cage washer to remove small pieces of apple, after which it is treated by one of several methods to prevent browning. This latter step is one of the most important in the production of

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[b] Presented before the Eighth Annual I. F. T. Convention, Philadelphia, Pa., June 9, 1948.

good-quality frozen sliced apples. The apple slices are then packed in containers, with or without added sugar or syrup. The packages of apples may be frozen immediately, or if sulfur dioxide is used as the anti-darkening agent the packaged slices are usually held several hours before being frozen in order to permit complete penetration of the sulfur dioxide into the slices.

Methods of Preventing Darkening

In freezing sliced apples it is essential that they be given a treatment to prevent the normal darkening that occurs during processing and subsequent thawing. This darkening or brown discoloration is well known and is caused by enzymic oxidation. Several different procedures for preventing discoloration have been proposed and used with apparent success in commercial practice. In the processing plant itself, if a delay occurs between the peeling and treating operations, the sliced apples should be held in a dilute salt (NaCl) brine (approximately one percent) to prevent or retard browning.

1. *Blanching:* Blanching has been used in many commercial operations. In this procedure the sliced apples are blanched in steam, hot water, or hot syrup long enough to inactivate the oxidative enzymes present in the apple tissue. Steam is generally considered to be the preferable blanching medium because less loss of soluble solids and flavor occurs. The blanching time required depends upon the thickness and texture of the apple slices. It is necessary that the slices be completely heated through to the center. Cruess and Seagrave-Smith *(4)* reported that a 3 to 5 minute steam blanch on a continuous screen was sufficient to inactivate oxidase enzymes. The blanched slices must be cooled rapidly and this presents another problem. In some cases spray-cooling with cold water followed by fluming in cold water has been used, but this method results in a further loss of flavor and soluble solids. According to the Western Regional Research Laboratory, Department of Agriculture *(19)*, the total weight loss during blanching and water cooling may be as much as 20 percent. Mazzola *(13)* pointed out that in commercial practice, after steam blanching, the apple slices could be put through a cooling vat in which the water was recirculated. The vat is filled in the morning with water which is used all through the day's operation. As the process goes on, the water picks up apple solids and flavors. This was said to reduce loss of flavor and to aid in producing a superior product.

Cruess *(3)* and Cruess and Seagrave-Smith *(4)* emphasized the fact that water cooling and fluming are objectionable from the standpoint of loss of nutrients and damage to flavor. They recommended that air cooling be used. Apple slices one layer deep, steamed on trays for four minutes, were cooled to 72° F. (22.2° C.) in less than four minutes in the air from a fan by evaporative cooling from the surface of the slices. This method was considered preferable to water cooling as the loss of soluble solids is cut to a minimum. They also indicated that apple sauce and pies were less flavorful when made from blanched apples than when made from raw fruit. More recently Joslyn and Hohl *(9)* indicated that blanching is entirely satisfactory if the time is carefully controlled and excessive losses of soluble flavoring and nutrient constituents during cooling are prevented. In blanching it is important that the slices be kept uniform in order to insure complete heat penetration without overheating. They reported that for apples cut into twelfths, the blanching time is usually 1½ to 2 minutes in free flowing steam 200°-212° F. (93°-100° C.).

2. *Deaeration:* Deaeration of sliced apples, either under vacuum or by exhausting the tissue oxygen through respiration while submerged in a dilute salt brine, has been employed to prevent or retard browning. In deaeration procedures the gases in the apple tissue are usually replaced by water, brine or syrup. Sliced apples treated in this manner generally have a waterlogged appearance. Mazzola *(12)* has indicated that canned apples so treated showed a greater degree of shrinkage when baked in pies. Deaeration methods have been used commercially for treating sliced apples which were to be canned. Several patents have been granted covering various applications of these procedures.

3. *Sulfur Dioxide:* Sulfurous acid or sulfites have been widely used in the preparation of frozen apples. Methods for the use of these compounds to prevent darkening are well known and have been described by a number of authors. They are easy to use and require only simple equipment. A very complete description of the use of sulfurous acid and sodium bisulfite in the commercial preparation of frozen sliced apples was made available by the United States Department of Agriculture *(19)*. It was emphasized that the simplicity of the process may lead to neglect of rigid control of the sulfur dioxide content of the dipping solution. It is of utmost importance that the sulfur dioxide content of the apples be kept at a minimum in order not to impair their flavor. Liquid sulfur dioxide, sodium bisulfite, sodium metabisulfite or potassium metabisulfite may be used as a source of sulfur dioxide in the dipping solution. Dipping times of one to five minutes in a solution containing 2,000 to 2,500 p.p.m. sulfur dioxide have been found to be satisfactory under a number of conditions. With this procedure it is usually recommended that the apple slices be held six to eight hours before they are frozen in order to permit complete penetration of the sulfur dioxide. Joslyn and Hohl *(9)* favor the use of 3,000 to 4,000 p.p.m. sulfur dioxide in the dipping solution with a dipping time of three or four minutes. They indicate that under these conditions a holding period prior to freezing is not required.

In work with McIntosh apple slices during the past three years we have found that a five-minute dip in a solution containing from 1,000 to 1,500 p.p.m. of sulfur dioxide gave good protection from darkening. Frozen slices treated in this manner were found to contain approximately 100 p.p.m. of sulfur dioxide. After being baked in a pie the sulfur dioxide content was reduced to from 10 to 20 p.p.m.

4. *Ascorbic and Other Acids:* During the past few years the addition of ascorbic acid to frozen fruits to prevent browning has become common practice. While this treatment has proved quite successful with some fruits, such as peaches, its use with sliced apples has

presented a problem because of the difficulty of getting the ascorbic acid to penetrate to the center of the slices. Suggested procedures for use of ascorbic acid with frozen apples have been described by Hoffman-LaRoche Inc. *(8)*, Merck and Company, Inc. *(14)*, Chas. Pfizer and Company *(17)*, and others. Bauernfeind and Siemers *(1)* and Bauernfeind, Smith, and Siemers *(2)* have discussed methods of processing frozen sliced apples with ascorbic acid in some detail. Advantages attributed to the use of ascorbic acid to prevent browning are that it does not introduce foreign flavors or odors, no heat is required, and the natural soluble solids and flavors of the apple are better retained. The above authors have stressed the fact that "The successful use of ascorbic acid in dry sugar or syrup packs of sliced apples depends on the use of specific processing methods." Two methods were suggested to avoid core browning during thawing. One method depended upon the use of thin or flat slices to permit adequate penetration; while the alternative method depended upon exhausting the internal gases of slices of ordinary thickness by a deaeration procedure. When the slices are filled into the containers, it is important that they be pressed down to form a compact mass which is covered with syrup or juice. In the successful use of these methods variations in maturity, texture, etc., of the apples must be considered and the procedures adapted accordingly.

The addition of ascorbic acid to blanched apples has also been suggested and in practice has been found to exert a favorable effect on the quality.

Sliced apples frozen with sugar or syrup contain an excess of syrup or juice when thawed out. This extra liquid is objectionable to some bakers who prefer a dry pack. On the other hand this syrup or juice may be concentrated and added to the pies when they are being baked. Such a procedure has been found to yield a very fine flavored pie.

Maintaining Firmness in Frozen Sliced Apples

As has been described by Kertesz *(10)*, Esselen, Hart and Fellers *(6)*, and Hills, Nevins, and Heller *(7)*, a treatment with small amounts of calcium chloride offers an effective method for maintaining firmness in apples that tend to become excessively soft and mushy after being frozen and cooked. The slices may be held for a few minutes in a solution containing 0.05 to 0.10 percent calcium chloride before being blanched, or if the apples are being treated with sulfur dioxide the calcium chloride may be incorporated in the same dipping solution. This compound may also be used in methods involving the use of ascorbic acid to prevent browning.

Variety and Condition of Apples Prior to Freezing

As with other fruits, the variety of apples selected for freezing can have an important bearing on the quality of the finished product. Tressler and Evers *(18)* have recommended the following: In the East the Greening was considered one of the best varieties for freezing and other recommended varieties included the Baldwin, Northern Spy, Winesap, Stark, Jonathan, and Rome Beauty. In Utah the Newtown Pippin, Rome Beauty and Winesap are frozen commercially. In the Pacific Northwest, Diehl, Wiegand, and Berry *(5)* recommended the Yellow Newtown, Winesap, Spitzenburg, Stayman Winesap, and Jonathan for freezing. According to Joslyn and Hohl *(9)*, the Yellow Newtown is the only commercial variety in California suitable for freezing for pie stock. The Gravenstein is not generally considered suitable and has been frozen chiefly as apple sauce.

In selecting apples for freezing their ultimate quality when baked in a pie should be emphasized, as frozen apples are used almost entirely for this purpose. With apples which have a good flavor but whose flesh tends to have a soft texture, such as the McIntosh, which is grown extensively in the Northeast, a calcium treatment is useful in improving their texture and pie-making qualities. The maturity of the apples and the storage conditions to which they have been subjected can also have a marked effect on the quality of frozen apples. Fruit which is overripe or has been stored too long or under poor conditions will tend to be inferior in texture and flavor. The firmer varieties of apples tend to stand up better in storage than do the softer varieties.

Discussion

As evidenced by the annual production of frozen sliced apples during the past few years this product enjoys a prominent position among the frozen fruits. On a basis of commercial experience and practice it would appear that there are several procedures which can be employed in producing a product of satisfactory quality. Of the different methods used to prevent darkening, such as blanching, deaeration, sulfurous acid dips, ascorbic acid, syrups and others, each has certain advantages and disadvantages.

The selection of which anti-darkening method to use may depend upon the volume of production, plant facilities, and demands of the consumer. For example, the use of sulfurous acid is a simple method but is banned by some states. Apples so treated may have a residual sulfur dioxide flavor unless care and control are exercised during the operation. Blanching causes some loss of flavor and solids but does not impart off-flavors. The use of ascorbic acid, in one of the methods that have been proposed, can yield good results if specific procedures are followed which are applicable to the particular raw material and plant operation. The use of sugar or syrup in conjunction with ascorbic acid or other treatments may present a problem in that the apples when thawed will have an excessive quantity of syrup and juice. Some users may object to this excess syrup as being a waste of sugar and apple flavor. On the other hand the syrup is a valuable adjunct to the frozen apples in providing protection against oxidation during freezing and thawing. It can also be used very effectively if it is drained from the thawed slices, concentrated, and added to the pie. Some bakers even handle the sugar in this manner when making pies from fresh apples.

In tests carried on at this institution during the past three years it has been found that all of the previously discussed methods of preventing browning can be used successfully in the preparation of satisfactory frozen sliced apples, if the necessary precautions and control measures are taken. As has been reported by others,

we have observed that blanching, while effective, does not permit as great a retention of the fresh apple flavor as do other procedures.

As a routine procedure, in the course of our investigations, samples of frozen apples have been baked into pies for final evaluation. Frequently pies were made from fresh apples of the same variety for comparison. It has been a common obesrvation that pies made from properly prepared frozen apples were superior in fresh apple flavor and aroma to pies made from untreated fresh apples. It is apparent that the effectiveness of anti-darkening and antioxidant treatments given frozen apples carry through into the finished pie and tend to stabilize the apple flavor. Similar observations have been made in the case of fresh sliced pie apples which are prepared for the bakery trade by some processors. On a basis of these observations it appears that the use of suitable antioxidants in pies made from fresh apples are worthy of consideration from the standpoint of maintaining optimum flavor. Pictures of pies made from frozen apples, are shown in Figures 1, 2, and 3.

FIG. 1. Pie made from untreated frozen McIntosh apples.

Apple Ice Cream Mix: Attempts to make an apple ice cream are not new but in general this product has not been produced very extensively. Two of the principal problems involved in the production of apple ice cream are: (1) difficulty in imparting a marked and distinctive apple flavor to the product and (2) the public acceptance of an apple-flavored ice cream. Methods of producing an apple flavor concentrate or essence (Milleville and Eskew, *16*) or "volatile apple concentrate" (Milleville, *15*) offer a means of enhancing the flavor of apple ice cream. At a "Conference on Apple Products" held January 22, 23, 1947 at the Eastern Regional Research Laboratory, Philadelphia, Pa., the use of apple essence in ice cream and sherbet was suggested and discussed by representatives of that laboratory and the New York Agricultural Experiment Station, Geneva.

Some success has been achieved in this laboratory in the preparation of a frozen apple for ice cream. An effort was made to prepare a product which would impart not only a distinctive apple flavor to the ice cream but also small distinct pieces of apple. The apples were cubed and given a treatment with calcium chloride in an effort to keep the pieces from breaking up to much during freezing. The procedure used was as follows:

McIntosh apples were washed, peeled, cored and cut into half-inch cubes. The cubed apples were dipped for

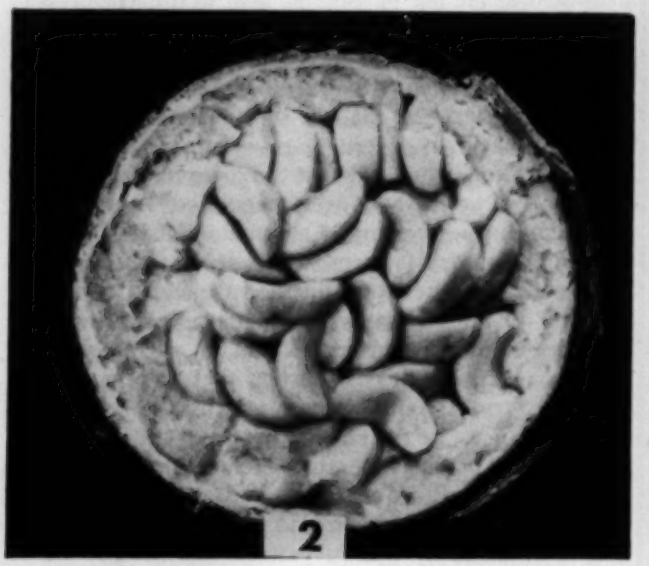

FIG. 2. Pie made from frozen McIntosh apples treated with sulfur dioxide.

FIG. 3. Pie made from frozen McIntosh apples treated with sulfur dioxide and calcium chloride.

15 minutes in a solution containing 5 percent salt (NaCl), 0.4 percent ortho-phosphoric acid, 0.4 percent ascorbic acid and 0.1 percent calcium chloride; then thoroughly mixed with sugar in the proportion of five parts apple to one part of sugar and allowed to stand one hour. The apples and juice were then packed solidly into No. 10 (603 x 700) enameled cans (ap-

proximately 6¾ lbs. net wt.). As the cans were being filled, 90 ml. (approximately 3 fl. oz.) of 135-fold apple essence[c] were mixed into the contents of each can. The cans were then sealed and frozen at —10° F. (— 23.3° C).

The cans of frozen apples were thawed at room temperature prior to use in ice cream. One No. 10 can of the apples was mixed with 45 pounds of a standard ice cream mix having a 12 percent butter-fat content. Two ounces of vanilla were added as it was found that it improved the flavor. The mix was frozen in a commercial type freezer.[d] The resultant ice cream had a pleasant but mild apple flavor—too mild in the opinion of some persons. The flavor could be accentuated by the further addition of the apple essence. As compared with control samples the calcium-treated apple cubes were not completely disintegrated in the freezing process, and small bits of apples were evident in the finished product. The pieces of apple themselves had a very good apple flavor. The addition of a small amount of cinnamon (approximately 4 teaspoons per 45 pounds of mix) has also been found to be effective in imparting a pleasant flavor to apple or apple sauce ice cream.

Peeled Whole Apples: Frozen peeled whole apples may have some merit as a specialty product, and have been found to make a tasty and colorful salad or dessert fruit.

McIntosh apples were washed, peeled and cored according to the method of Lee *(11)* in which the blossom end is left on the apples. The apples were then cooked slowly in a 40 or 50 percent sugar syrup containing 0.1 percent calcium chloride until they were cooked through (approximately five to eight minutes). The apples were then cooled on a screen by a cold air blast. When cool the apples were placed in paper cups such as are sometimes used for canned or frozen baked apples. The apples may be packaged and frozen immediately or the core cavities may be filled with an appropriate filling prior to freezing.

After they are thawed out, the apples may be filled as desired by the consumer. In practice we have found that whole cranberry sauce or fresh cranberry-orange relish makes a colorful filling and the flavor combination with the apple is quite acceptable. Plain frozen apples and apples which were filled with cranberry sauce and cranberry-orange relish prior to freezing are shown in Figures 4 and 5, respectively.

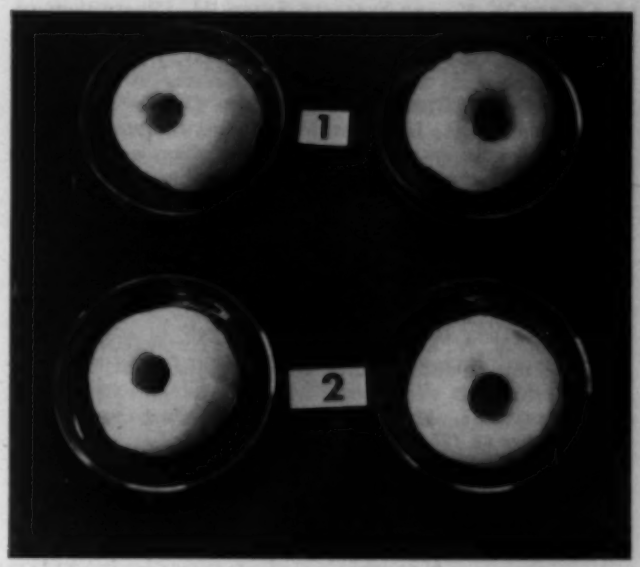

FIG. 4. Frozen peeled and cored McIntosh apples blanched in 40 percent syrup.

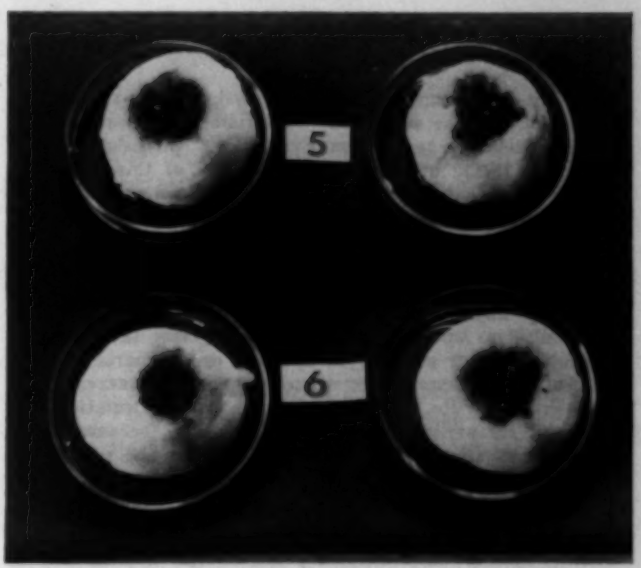

FIG. 5. Frozen peeled and cored McIntosh apples blanched in 40 percent syrup. (No. 5, filled with whole cranberry sauce; No. 6, filled with cranberry-orange relish.)

Summary

Methods of freezing sliced apples are reviewed and discussed. Procedures for preventing discoloration and for maintaining firmness and texture of the slices are pointed out. Experimental tests have shown that methods of preventing darkening and oxidation also exert a favorable effect in retaining the original fresh flavor of the apple with the result that apple pies made from frozen sliced apples may be superior to pies made from freshly sliced apples in fresh apple flavor and aroma. Methods for the preparation of an apple ice-cream mix and frozen peeled apples with filled cores suitable for salad or dessert use are described.

[c] Supplied through the courtesy of the U. S. Department of Agriculture, Eastern Regional Research Laboratory, Philadelphia, Pa.

[d] Acknowledgment is due Mr. Frank T. Canavan of the Department of Dairy Industry for his cooperation and advice in freezing and evaluating the lots of ice cream which were prepared.

LITERATURE CITED

1. BAUERNFEIND, J. C., AND SIEMERS, G. F. Methods of freezing sliced apples with l-ascorbic acid. *Fruit Prod. J.*, **26**, 4 (1946).
2. BAUERNFEIND, J. C., SMITH, E. G., AND SIEMERS, G. F. Processing frozen sliced apples with l-ascorbic acid. *Fruit Prod. J.*, **27**, 68 (1947).
3. CRUESS, W. V. Blanching and cooling for frozen pack. *Fruit Prod. J.*, **25**, 134 (1946).

4. Cruess, W. V., and Seagrave-Smith, H. Observations on freezing of apples. *Fruit Prod. J.*, **26**, 36 (1946).
5. Diehl, H. C., Wiegand, E. H., and Berry, J. A. Preservation of fruits and vegetables by freezing in the Pacific Northwest. U. S. Dept. Agr. Mimeo. *Circular* **53**, 58 pp.
6. Esselen, W. B., Jr., Hart, W. J., Jr., and Fellers, C. R. Further studies on the use of calcium chloride to maintain firmness in canned and frozen apples. *Fruit Prod. J.*, **27**, 8 (1947).
7. Hills, C. H., Nevin, C. S., and Heller, M. E. Firming apple slices. *Fruit Prod. J.*, **26**, 356 (1947).
8. Hoffman-La Roche, Inc. Processing frozen fruit with l-ascorbic acid (vitamin C). Rev. Ed. 27 pp. Nutley 10, New Jersey (1946).
9. Joslyn, M. A., and Hohl, L. A. The commercial freezing of fruit products. Calif. Agr. Expt. Sta. *Bull.*, **703**, 108 pp. (1948).
10. Kertesz, Z. I. The effect of calcium in plant tissues. *The Canner* **88** (7), 26 (1939).
11. Lee, F. A. The preservation of baked apples by freezing. *Fruit Prod. J.*, **26**, 360 (1947).
12. Mazzola, L. C. Factors in apple canning that make better pies. *Food Ind.*, **2**, 111 (1930).
13. Mazzola, L. C. Fruit processing improved. *Food Ind.*, **17**, 134 (1945).
14. Merck and Company, Inc. Ascorbic acid Merck as an antioxidant in fruit and food products. 12 pp. Rahway, New Jersey (1947).
15. Milleville, H. P. Present status of the manufacture and use of volatile fruit concentrates. *Fruit Prod. J.*, **27**, 99 (1947).
16. Milleville, H. P., and Eskew, R. K. Recovery and utilization of natural apple flavors. *Fruit Prod. J.*, **24**, 48 (1944).
17. Pfizer, Chas., and Co., Inc. *Ascorbic and Citric Acids in Frozen Foods.* 48 pp. New York 7, New York (1948).
18. Tressler, D. K., and Evers, C. F. *The Freezing Preservation of Foods.* 2nd Ed., The Avi Publishing Co., Inc., New York, N. Y. (1947).
19. U. S. Dept. Agr., Western Regional Research Laboratory (Albany, Calif.). Commercial preparation and freezing preservation of sliced apples. AIC-57, rev., mimeo. 7 pp. (1945).

Further Considerations Relating to Evaluation of Thermal Processes for Foods

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This paper supplements the analysis which was carried out by the author in "Bacteriological Considerations Relating to Process Evaluation," published on pages 115-132 of the April, 1948 issue of this Journal. The analysis is extended to include a graphical integration for determining the number of bacteria (or spores) of known heat resistance, which willl survive in a given container of food during any designated thermal process. The author discusses the desirability and significance of basing thermal process calculations upon the requirement of giving the same probability of survival of spoilage organisms in the location in the container where probability of survival is greatest. He proposes this method of calculation, except for arriving at reference processes, because it is less laborious than that of integrating the probabilities of survival in all locations within the container.

A method has been presented *(3)* for ascertaining the location in the food container where the probability of bacteria surviving a given thermal process should be greatest. The accompanying analysis considering both the order of death of bacteria and the mechanism of heat transfer within the food container demonstrated that lethality of heat treatment at the point of greatest temperature lag in the container of food is often not a true criterion of the sterilizing capacity of a thermal process.

The purpose of this paper is to present further developments in this connection, including a method for integrating probabilities of bacterial survival at all locations in the container and thereby permitting of an accurate estimation of the absolute [a] probability of bacterial survival in a container of food subjected to a given thermal process and containing any given number of bacteria of known resistance to heat. For the sake of brevity, considerations brought out in the above mentioned publication will be repeated here only if it is felt that they are necessary to the continuity of thought. In other words, this paper should be considered as a continuation of the previous treatment *(3)*.

[a] The word absolute as used in this paper in connection with probability denotes the probability of survival per container, or the sum of probabilities of survival in all the different designated locations within the container.

General Considerations

For the purpose of theoretical analysis the food in a container has been divided into a number of hypothetical layers which increase in volume from geometric center to periphery. In order to picture the decrease in severity of heat treatment from outside to center of the mass of food, a series of cylindrical containers are visualized which range in size from one the size of the food container to one the size of a short piece of pencil lead. By considering the containers as decreasing in size progressively in accordance with a uniform decrease in length and diameter, they may be pictured as being placed one inside the other from largest to smallest such that the geometric center of each imaginary cylindrical container is common with the geometric center of the real container. Between the walls of any two successive containers there would be a layer of food the thickness of which may, for the purpose at hand, be considered as equal to the distance, along a common radius, between the walls of the two containers. Obviously, the volume of food in such a layer would be equal to the volume of the larger container less the volume of the smaller container. Any number of such layers may be visualized as existing within a given container of food.

It has been pointed out *(3)* that, for any given thermal process, the decrease in severity of heat treatment from the outside to geometric center of the real container is related to the decrease in surface area of these imaginary cylindrical containers. Also that the number of bacteria at the surface of one imaginary cylinder would bear the same relation to the number of bacteria at the surface of another as the surface area of the one cylinder bears to

the surface area of the other. In the strictest sense this concept visualizes food layers which are infinitesimal in thickness, and if the concept were adhered to in solution of a process evaluation problem a complicated mathematical treatment would be involved. However, by assuming the layers of food to have some finite thickness a complicated problem is greatly simplified. In thus extending the concept, it may be said that the decrease in heat treatment and the decrease in number of bacteria per layer of food from outside to center of the food container are related to the decrease in volume of food per layer from outside to center of the container. In the method proposed for ascertaining the location in the container where probability of bacterial survival is greatest, the value 0.3 cm. was used to represent layer thickness. This value was chosen purely as a matter of convenience since it was realized that for ascertaining the location of greatest probability of survival the layer thickness makes very little difference so long as the layer is not so thick that the severity of the heat treatment at one side of the layer is greatly different from that of the heat treatment at the other side. Naturally the smaller the value chosen for layer thickness the more accurately will the location of greatest survival probability be determined.

For determination of the absolute probability of survival in the food container, the same may be said with reference to the magnitude of values chosen to represent layer thickness. The number of layers per container may be obtained by dividing the radius by the assumed layer thickness; or, the number of layers may be fixed at some value (say 25) for all container sizes and the layer thickness computed for each container size. Since the determination of absolute probability of survival in the container entails the integration of the probabilities of survival in all of the layers within a container, it is believed that from the standpoint of comparing lethality of processes for different products in containers of different sizes it would be more convenient to assume that a fixed number of layers should exist per container, regardless of container size or shape, and that the layer thickness should vary in accordance with variations in container radii.

Based on principles stated elsewhere *(3)* it is possible to determine the probability of survival in any of the designated layers in the food container if the temperature distribution pattern during thermal processing is known, and if the number of bacteria to be destroyed and the thermal resistance of these bacteria are known. Temperature distribution patterns for any given food during process in a container of any given size may be determined experimentally. The calculation methods of Olson and Jackson *(2)* may also be employed if the product heats by conduction. Thermal resistance values may be determined for the bacteria known or assumed to be present. Some value to represent the number of such bacteria which are likely to be present per unit volume of product must be assumed. For the establishment of processes with equivalent sterilizing capacity it is suggested that ten spores of the putrefactive anaerobe 3679 are assumed to be present per cc. of product. Zeta (Z) values for spores of this organism will, for low-acid food products, fall in the range, $Z = 1$ to $Z = 2$ for a process temperature of 250° F. (121.1° C.). For the purpose at hand the value of Z will be taken as 1.5.

For the purpose of determining and integrating probabilities of survival it will be assumed that any container of food, regardless of container size and shape, is divided into 25 imaginary layers of food in accordance with principles already discussed. The thickness of any layer in the food container would then be equal to the container radius divided by 25. It should be noted here that container dimensions should be taken as the inside dimensions of the closed container for the purpose of ascertaining absolute probability of bacterial survival.

The inside dimensions, along with can volume and food layer thickness (assuming 25 layers per can) for a few common can sizes have been listed in Table 1.

TABLE 1

Relationship of can size, can volume, and thickness of hypothetical food layers for some common can sizes.

Can Size			Food Layer Thickness (cms.) 25 Layer/can	Approximate can volume (cc.)
Canner's Designation	Approximate Inside Dimensions (cms.)			
	Diameter	Height		
211 x 304	6.509	7.303	0.130	243
301 x 411	7.461	10.954	0.149	479
307 x 409	8.414	10.636	0.168	591
603 x 700	15.398	16.828	0.308	3134

Since temperature distribution data are available for five percent and one percent suspensions of bentonite in No. 10 (603 x 700) cans *(1)*, this can size has been chosen for development of further considerations. Assume we have two foods in which the resistance of P. A. 3679 spores is identical. Further assume that one of the foods heats as did the five percent bentonite, the other heats as did the one percent bentonite, and that each food is inoculated with P. A. 3679 spores, at the rate of 10 spores per cc. A can of either product would then contain approximately 31,340 spores. What process, in terms of time at a retort temperature of 250° F. should be used for each type of product in order to accomplish the same reduction in total number of spores per can or per any given number of cans?

In solution of the problem it is most convenient to proceed, up to a point, in the same way as described elsewhere *(3)*. Values for establishing the F requirement curve are given in Table 2.

TABLE 2

F values required to reduce the number of P. A. 3679 spores (Z = 1.5 at 250° F.) in the designated locations to 0.001 spore per location

Initial number of spores/location	F value required to reduce number to .001
1 = center	4.5
128 = surface area of imaginary cylinder 2.54 cm. in diameter x .308 (layer thickness) x 10 (no. spores/cc.)	7.66
444 = surface area of imaginary cylinder 5.08 cm. in diameter x .308 x 10	8.47
945 = surface area of imaginary cylinder 7.62 cm. in diameter x .308 x 10	8.96
1634 = surface area of imaginary cylinder 10.16 cm. in diameter x .308 x 10	9.31
2520 = surface area of imaginary cylinder 12.70 cm. in diameter x .308 x 10	9.59
3340 = surface area of imaginary cylinder 14.73 cm. in diameter x .308 x 10	9.78

It may be noted that the number of spores per layer was determined by multiplying the surface area of each imaginary cylinder by the food layer thickness and the number of spores per cc. This method of arriving at the number is simple and it gives essentially the same value for each layer as would be obtained if the volume of the layer to be multiplied by number of spores per cc. were arrived at by determining the difference in volumes of two properly chosen imaginary cylinders differing in diameter by 0.616 (2 x layer thickness) and differing in height by the same amount. Also, the method permits of using the F value of the heat treatment at the surface of the imaginary cylinder as that characterizing the heat treatment for the entire layer. Since approximately one-half the food in the layer would be on either side of the wall (infinitesimal thickness) of the imaginary cylinder and since the layer thickness is small the F value for the heat treatment at the wall would closely approximate the average F value given all the food in the layer. The convenience of the method will become evident as we proceed with the problem. It may also be noted that the value, one, is considered as representing the number of spores lying at the geometric center. Theoretically the number should be zero, and the smaller the number assumed to be present at this point, the more accurate will be the evaluation; however the number may be varied from a small fraction of a spore to several spores without causing appreciable variation in process values arrived at. It is convenient to assume that one spore is always located at the geometric center. Another point which should be mentioned with reference to the values appearing in Table 2 is that they are for layers which do not necessarily coincide with any of the 25 hypothetical layers into which the container is visualized as being divided for the purpose of integrating total probability of survival. It is not necessary that they coincide so long as the diameter of any imaginary cylinder employed for establishing an F requirement value is as much less than the diameter of the real container as the height of the imaginary container is less than the height of the real container.

Figure 1 shows the relative capacities of heat treatments, at different locations in the container, to reduce the number of spores at these locations. Curve 1 is an F requirement curve based on values in Table 2. Curve 2 is the F distribution curve representing the F values obtained at different locations in the five percent bentonite suspension when the process is sufficient to give an F value of 4.5 for the heat treatment at the geometric center. Curve 3 is an F distribution curve representing the F values obtained at different locations in the five percent bentonite suspension when the process is such that 0.001 spore will survive at the location where probability of survival is greatest. Curves 4 and 5 are corresponding F distribution curves for the one percent bentonite suspension. Curves 3 and 5 represent the F distribution in the five and one percent bentonite suspensions given processes equivalent with respect to their capacity for reducing to the same level the number of spores at locations in the two products where probability of survival is greatest. Note should be made of the procedure for locating adjusted curves such as Curves 3 and 5 in Figure 1. For example, in arriving at Curve 3 from Curve 2, a hypothetical line was taken parallel to the F requirement curve and tangent to Curve 2. The point of tangency represented the location in the container where probability of survival was greatest. It was then possible to locate a point on the F requirement curve representing the intersection of the F requirement curve and a line perpendicular to the x-axis which would pass through this point of tangency. The point on the F requirement curve so located also represented a point on an F distribution curve describing a process of such capacity that it would reduce the number of spores to 0.001 at the location in the container where probability of survival would be greatest. Knowing the temperature distribution pattern during process it was possible to calculate the length of process which would result in the indicated F value at this location in the container. Then knowing the length of process it was possible to calculate the F value which would characterize the heat treatment at any other location in the container. Plotting F values so calculated for different locations in the container the adjusted F distribution curve (No. 3) was obtained. Any F distribution curve may be readily relocated in this manner.

Upon inspection of the F distribution curves in Figure 1 it becomes obvious that the processes equivalent with

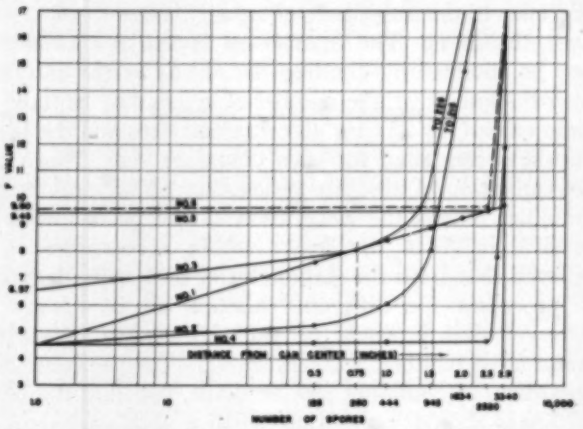

FIG. 1. Graphical depiction of relative capacities of heat treatments, at different locations in the No. 10 can, to reduce the number of P. A. 3679 spores at these locations.

Curve No. 1—F requirement curve for spores of P. A. 3679 (Z = 1.5 at 250° F.).

Curve No. 2—F distribution curve for conduction-heating product (5% bentonite in water) when F value of heat treatment at center is equal to 4.5.

Curve No. 3—F distribution curve for the same conduction-heating product when probability of survival is one in one thousand in the location where survival probability is greatest.

Curve No. 4—F distribution curve for convection-heating product (1% bentonite in water) when F value of heat treatment at center is equal to 4.5.

Curve No. 5—F distribution curve for the same convection-heating product when probability of survival is one in one thousand in the location where survival probability is greatest.

Curve No. 6—F distribution curve for convection-heating product characterizing a thermal process which allows an absolute survival probability equal to that allowed by the process, for conduction-heating product, characterized by Curve No. 3.

respect to reducing the number of spores at the locations of greatest survival probability are also very nearly equivalent with respect to reducing the number of spores per can. However, a true comparison can be made only by determining the number of spores per can which should survive each process. This can be accomplished only by some method whereby the number of spores

surviving in all of the designated locations in the can are summed up. The procedure which is used in the following analysis to show the relative capacities of processes described by the F distribution curves in Figure 1 is simple and believed to give sufficiently accurate values for most applications.

Graphical Integration of Survival Probabilities

The number of spores lying at the surface (in a layer 0.308 cm. thick for No. 10 can) of an imaginary container of any designated radius may be determined from the spore distribution curve (Figure 2). The approxi-

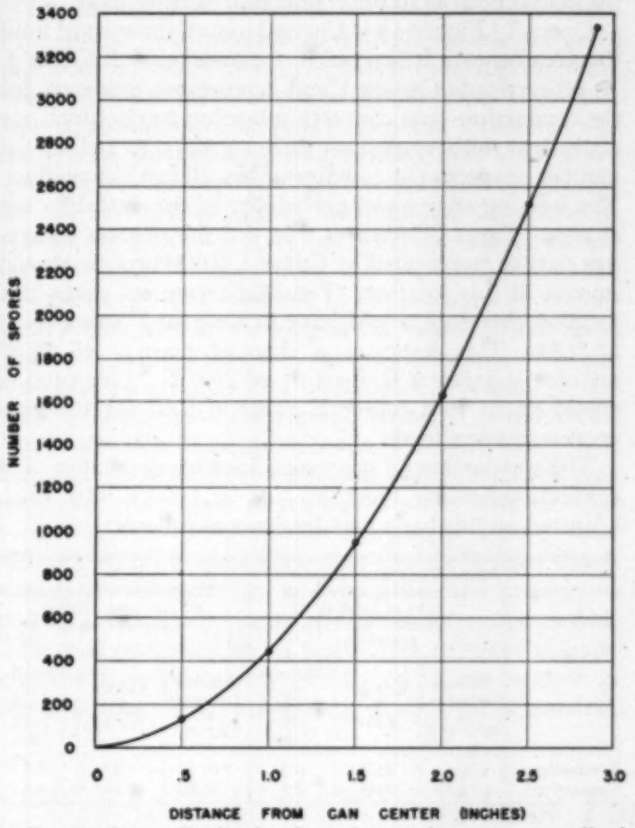

FIG. 2. Spore distribution from geometric center to wall of No. 10 (603 x 700) can, when the product contains ten spores per cc.—see text.

mate average F value to which the spores in any such layer are subjected may be determined from the F distribution curve characterizing the thermal process to be evaluated. The number of spores surviving in any layer after process, designated by the symbol b, may then be calculated using the equation:

$$b = \log^{-1} \frac{Z \log a - F\,Fi}{Z}$$

where:

$$F_i = \log^{-1} \frac{250 - RT}{z}$$

Z = slope, of rate destruction curve for spores heated at retort temperature (R T), expressed as the number of minutes required for the curve to traverse one log cyle.
a = number of viable spores in layer before process.
z = 18° F. (assumed value).

For the purpose of integration, 25 layers of food are considered to exist in any container. The number of spores surviving in each such layer may be calculated, and the total surviving per container of food may be determined by adding the 25 values thus obtained. However, a graphical summation is accomplished with greater ease and is sufficiently accurate for practical use.

The 25 layers are numbered 1 to 25 from the geometric center to the periphery. Plotting on plain coordinate paper, the layer number in the direction of abscissae against corresponding number of spores surviving, in the direction of ordinates, a curve is obtained the area beneath which is proportional to the total number of spores surviving per container. This curve may be termed the survival distribution curve. The number of spores surviving per container is obtained by dividing the area beneath the survival distribution curve by the area representing one spore in one layer, also determined from the same graph. A planimeter is used for measuring the different areas.

In establishing a survival distribution curve, it is not necessary to determine the number of spores surviving in each layer. The nature and position of the curve is usually well defined by no more than seven or eight points. Also as mentioned earlier spore survival values may be for layers which do not necessarily correspond to any of the 25 layers assumed for establishing the coordinates. The reason for this becomes obvious upon inspection of Figures 3 and 4. It should be noted that

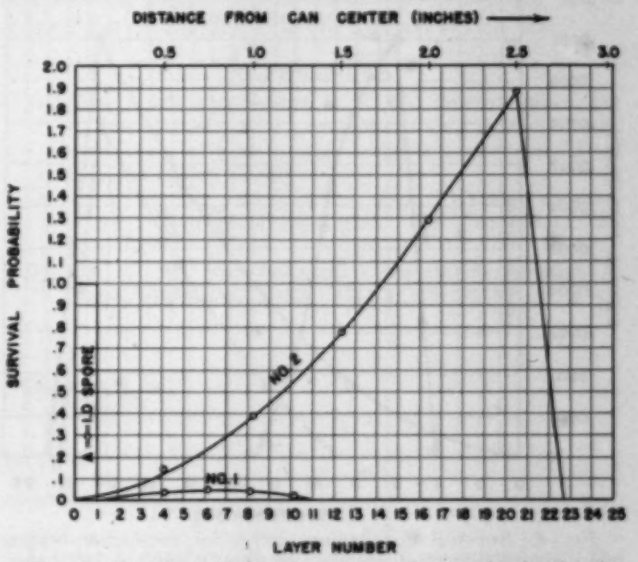

FIG. 3. Survival distribution curves for conduction-heating and convection-heating products in No. 10 (603 x 700) cans. Areas beneath curves are proportional to the number of spores surviving per can.

Curve No. 1—For conduction-heating product given thermal process of such capacity that the F value of heat treatment at geometric center of the product is equal to 4.5.
Curve No. 2—For convection-heating product given thermal process of such capacity that the F value of heat treatment at geometric center of the product is equal to 4.5.

all survival distribution curves if correctly plotted would be asymtotic to the base line representing zero survival probability; however, in most cases it is more convenient, and the accuracy sufficient, if they are plotted as shown in Figures 3 and 4. The areas omitted by allowing the curves in Figures 3 and 4 to intersect the zero probability lines are insignificant compared with the total areas beneath the curves representing total probabilities of survival.

Figure 3 shows survival distribution curves for two

cans of food (one heating as did the five percent and the other as did the one percent bentonite suspension) given thermal processes such that the same F value (4.5) is obtained at the geometric center of each can of food. Curve 1 is for spores in the conduction-heating food and Curve 2 for spores in the convection-heating food. Values for establishing these curves were arrived at from values taken from the spore distribution curve (Figure 2) and the F distribution Curves 2 and 4 in Figure 1. From Figure 3 it is found that the area representing survival of one spore in one layer is equal to 0.625 square inches. The area beneath the survival distribution curve for the conduction-heating food is equal to 0.20 square inches, and therefore represents survival of 0.32 spores (32 spores per 100 such containers). The area beneath the survival distribution curve for the convection-heating food is equal to 9.86 square inches, and therefore represents survival of 15.8 spores (1580 spores per 100 containers). In other words, thermal processes for the two products, resulting in heat treatments at the center having the same F value, would allow nearly 50 times as many spores of the assumed resistance to survive per unit volume in the convection- as in the conduction-heating food.

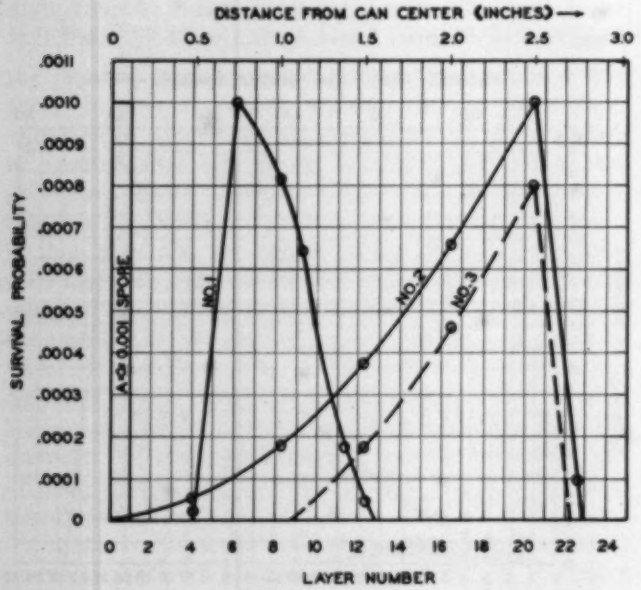

FIG. 4. Survival distribution curves for conduction-heating and convection-heating products in No. 10 (603 x 700) cans. Areas beneath curves are proportional to the number of spores surviving per can.

Curve No. 1—For conduction-heating product given thermal process of such capacity that probability of survival is one in one thousand in location where survival probability is greatest.

Curve No. 2—For convection-heating product given thermal process of such capacity that probability of survival is one in one thousand in location where survival probability is greatest.

Curve No. 3—Survival distribution curve for convection-heating product given a thermal process which allows an absolute survival probability equal to that allowed by the process given the conduction-heating food and characterized by the survival distribution Curve No. 1.

Figure 4 shows survival distribution curves for the same two products given thermal processes equivalent with respect to their capacity to reduce the number of spores at the location (in layer) where probability of spore survival is greatest, Curve 1 being for spores in the conduction-heating food and Curve 2 for spores in the convection-heating food. Values for establishing these curves were arrived at from values taken from the spore distribution curve (Figure 2) and the F distribution Curves 3 and 5 in Figure 1. From Figure 4 it is found that the area representing 0.001 spore in one layer is equal to 1.125 square inches. The area beneath Curve 1 is equal to 5.66 square inches, and therefore represents survival of .00453 spores. The area beneath Curve 2 is equal to 9.91 inches, and therefore represents survival of .00793 spores. Thermal processes for the two products equivalent with respect to their capacity to reduce the number of spores in the location where probability of spore survival is greatest would allow only 1.75 times as many spores of the assumed resistance to survive in the convection- as in the conduction-heating food.

Curve 3 (Figure 4) is Curve 2 moved downward until the area beneath it is equal to the area beneath Curve 1. In other words Curves 1 and 3 represent processes for the conduction- and convection-heating foods which are equivalent with respect to their capacity to reduce the number of spores per container (No. 10 can) of product. The location of greatest probability of survival does not change. Curve 3 indicates that, for the process equivalent to that represented by Curve 1, 0.0008 spores should survive at this location. The heat treatment given this location therefore would have to have an F value equal to 9.74. This indicates a thermal process of 16.80 minutes at a retort temperture of 250° F. This process would result in a center F value of 9.60 for the convection-heating food.

The comparison of processes, for the conduction- and convection-heating foods in No. 10 (603 x 700) cans, adjusted on this basis may be made as follows:

Product	Equivalent with respect to to reducing number of spores at location of greatest survival probability			Equivalent with respect to reducing number of spores per can		
	Process (minutes at 250° F.)	Center F Value	Remaining Spores/ 1000 Cans	Process (minutes at 250° F.)	Center F Value	Remaining Spores/ 1000 Cans
Conduction	226	6.57	4.5	226	6.57	4.5
Convection	16.55	9.45	7.9	16.80	9.60	4.5

Discussion and Summary

The graphical integration method demonstrated above makes possible a determination of the number of bacteria (or spores), of known heat resistance, which will survive in a given container of food during any designated thermal process. Demonstration of the method has further emphasized the fallacy in considering the point of slowest heating in a container of food as the point where probability of bacterial survival is always greatest. It is obvious from the foregoing analysis that there is no one location, within the food container, the sterility of which denotes sterility at all other locations.

By the methods described, an area within the container may be shown to be that area where probability of survival is greatest, but this does not mean that survival probability is zero in any or all other designated locations in the container. The probability of survival in the entire container can be determined only by integrating the probabilities of survival in all the designated locations (imaginary layers of food in the container according to method described). In this manner thermal processes may be specified which are equivalent with

respect to their leaving the same number of spores surviving per unit volume of product or per container of product. From the practical standpoint it would be more convenient to adjust processes such that they were essentially equivalent with respect to allowing the same number of spores to survive per container or per some given number of containers. Disregarding container size, probable survival would then be expressed as some given number of spores per so many containers (say 1000). Spoilage data are now commonly expressed in this way, that is, a number of cans spoiled per 1000 cans of product.

Comparing the probable survival in convection-heating and conduction-heating foods, which are given processes equivalent with respect to reducing the number of spores in the locations in the two types of product where probability of survival is greatest, it is found that the process for the convection-heating food allowed 7.9 spores to remain per 1000 No. 10 cans while the process for the conduction-heating food allowed 4.5 spores to remain per 1000 No. 10 cans. Such survival values are probably close enough from the practical standpoint. Furthermore, it is doubtful if the accuracy of experimental data used in arriving at the values is such as to justify assuming that they are significantly different. The heat penetration data on which the evaluation was based characterize the extremes, virtually, of convection and conduction heating for foods in No. 10 cans. It is logical to believe, therefore, that survival values estimated for processes adjusted on this same basis for other foods in No. 10 or smaller containers should show differences no greater than that for the values determined for the extremes of convection and conduction heating. This leads one to the obvious conclusion that, if thermal processes for all foods were adjusted so as to give the same probability of survival in the location in the container where probability of survival is greatest, the processes would from the practical standpoint be virtually equivalent with respect to allowing the same number of spores to remain viable per container or per any given number of containers. If processes were adjusted in this manner, the more laborious task of integrating probabilities of survival in all locations within the container would be unnecessary except for the purpose of arriving at reference processes.

It will have been noted that in the analyses thus far, the effect of product circulation during convection heating on spore survival within the container has not been discussed. The analyses have been based on the assumption that from the standpoint of process evaluation, convection-heating products may be treated as if no circulation of product occurs within the container. The question naturally arises: Would circulation of product through zones of different temperature, which does occur in convection heating, require consideration in the evaluation method? Unfortunately the nature of convection currents in food during heating are not well enough understood to make an exact analysis of the factor possible. Analysis based on the very limited information available indicates that even maximum circulation which could be visualized as occurring would not, if accounted for in the evaluation method, alter the calculated results appreciably. This and possibly other factors may when better understood indicate slight corrections or alterations in the method herein proposed.

REFERENCES

1. Jackson, J. M., and Olson, F. C. W. Thermal processing of canned foods in tin containers. IV. Studies of the mechanisms of heat transfer within the container. *Food Research*, **5**, 409 (1940).
2. Olson, F. C. W., and Jackson, J. M. Heating curves—theory and practical application. *Ind. Eng. Chem.*, **34**, 337 (1942).
3. Stumbo, C. R. Bacteriological considerations relating to process evaluation. *Food Tech.*, **2**, 115 (1948).

Mass Taste Panels[a]

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Dr. Elder has presented very ably the usefulness of small, well-screened panels of persons in evaluating differences of flavor, color, appearance, texture and other qualities which may be of importance in the development of a processed food. Measurements such as he has described are made under reproducible conditions, where the researcher can control the temperature of product, room lighting, air condition, quietness of surroundings and similar factors which help to make the appraisal of the judge more objective. The judgments of such panels can be exceedingly useful to the food technologist in determining the effect of small changes in the composition and quantity of materials as well as in the type of processing applied to the food combination under development.

My assignment in this discussion is concerned with the finished product after the technologist, chemist, engineer and home economist have carried their experiments to a stage which is reasonably satisfactory to those responsible for the development of the new food specialty. What the management now needs to find out is: Do Mr. and Mrs. Consumer find the proposed product acceptable as compared to similar items available on the market? Only when a favorable verdict is given by the public will most business managers feel confidence in proceeding to the next development step of offering the item to the trade in test markets. For food products this means that we must resort to techniques which employ mass taste panels and for this purpose the food technologist much seek the assistance of those skilled in market research. By teaming up the worker trained in laboratory development with the one experienced in

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finding how a market reacts the net result should be a reliable index of the consumer's preference for the particular type of product which is the goal of the company's research program. Much of what I shall have to say is the reflection of the experience of our own Market Research Department.

Frequently attempts are made to obtain such verdicts at a low cost through the use of a mass taste panel selected from among company employees. Such a group can never be considered as truly representative of the ultimate consumers. The number of judges will usually be too small, while the distribution of age, sex, income, and general intelligence probably will reflect the consumer at large only by accident. If one is working on improvement of an item already in the production line a panel chosen from company employees will probably be biased in favor of the present type of product, if for no better reason than that it is the one with which the individuals are most familiar. Reliance on a verdict obtained from such a panel may well prove ill-founded. However, assuming that a market sales test in one or two limited areas would be the next step in bringing the new food item into the sales portfolio of the company no great disaster is apt to follow from accepting the verdict of a company taste panel. But considerable money and effort would have been spent rather uselessly, while the loss of time thus occasioned is irrecoverable. If one resorts to so specialized a mass taste panel as the first step in measuring consumer preferences it should be done with a full appreciation of the limited value of an employee taste test group. Of course, we are ruling out completely any thought that a decision as to what the general public may prefer can be made by a single or a few company executives, as has too frequently been done in the past. We are trying to outline a reasonably sound experimental approach to the problem.

Mass investigations have been developed in the United States for all sorts of sampling of public tastes and ideas. Gallup polls have become household words throughout the nation. Let us consider for a bit what a food management should and should not expect to learn from a mass taste panel. In the first place, the public will not tell you whether the proposed item will sell. What they will tell you is the relative preference between your new product and some other similar item which people may be able to buy or may have used. The latter, for your purposes, becomes the reference standard. Your presentation of the new and the reference items must be such as not to influence the preference choice in any way or your purpose will be defeated. In presenting samples to a mass taste panel for selection on a quality or preference basis the number of samples should be limited to two. One cannot expect an untrained panel to return a valid verdict when preferences between more than two food products are involved.

The next point to bear in mind is that you must not seek answers which require the mass of judges to exercise their imagination. They can only answer such questions as they are qualified to answer out of their own experience. One should not expect them to visualize what your product will look like when it reaches the grocers' shelves. The consumer cannot predict in advance what his response may be to the advertising which you plan to use for promoting your new specialty. He is not apt to give a valid answer as to purchasing at some projected selling price. Certainly he is in no position to know with certainty that he would buy your item in preference to some other brand. He can, and usually will, tell you whether he prefers your cake mix to some other cake mix which you submit to him in an identical package. He is able to say which he likes the better, assuming that there is a distinguishable difference between the two samples. But do not expect to obtain more information from your mass taste panel than it is in a position to furnish on a judicious basis.

A further consideration which should be kept in mind is that one must rigorously exclude certain factors which might exercise a psychological effect on the individual's choice. Among these is the prestige of a brand name or of a company identification which must be eliminated by the use of coded packages of identical appearance. There should be no reference in any way to the fact that one of the products is new, since this will affect choice, either consciously from the desire to please or unconsciously because a yearning for that which is novel is a common human trait. There should be no inquiry which carries implications of economic status or social class. For example, a house-to-house survey of the number of towels sent to the laundry weekly turned up an average figure two times greater than actual check counts made at the laundry over a six-week period indicated was the fact. The plausible explanation given for this discrepancy was that the greater the number of towels dirtied each week the higher one's place in the rat race of keeping up with the Joneses. Thus Mrs. Smith tended to claim a much higher towel usage than was actually the case.

These reflections emphasize the importance of the wording used in preparing questions which are to be addressed to the members of the mass panel. Not—"What soap do you use for fine underthings?"—to which the response might be, "Lux!"—an expensive form of soap which Mrs. Housewife may not use at all. Rather query, "What soaps do you consider satisfactory for fine underthings?"—to which she replies "Ivory Flakes or Rinso or Super-Suds." This does not tell you which she uses, but does give her opinion as to what she considers the nature of a satisfactory detergent for lingerie to be. You would certainly be sure that she did not favor a product such as "Vel" for this purpose, possibly because she was not familiar with this type. If one were trying to get some idea of an acceptable price range for the new product one would do much better not to ask Mrs. Johnson if she would pay 29c for a package, or if she would buy it at 35c, but rather what Mrs. J. thought her friends or neighbors might be willing to pay for it.

Having these several points in mind let us now consider specific techniques to be adopted for our mass taste panels. First—how shall the panel be selected? The cardinal principle here is that the sample of population taken must be representative of the whole which is being evaluated. This statement seems almost too elementary to merit enlargement. But consider what happened when a chain of newspapers undertook a survey of the

soap buying and soap using habits of the South. The picture which this survey came up with was so at variance with sales experience of the manufacturers that one of them decided to look into the methods used in the newspaper study. Imagine the amazement caused upon learning that questionnaires had been sent out through Parent-Teachers Associations only. A most convenient and cooperative group, to be sure, but one which in the South had no negro members. And this in areas where the blacks outnumbered the whites sometimes as much as two or three to one.

Some years ago I had occasion to decide on how to test the acceptability of a new chocolate syrup to be used for making a pasteurized chocolate milk to be distributed on company milk routes. Preliminary checking indicated that probably two-thirds or more of all bottled chocolate milk was consumed by children of grammar school age and that much of it was drunk between meals. In considering how to select a mass taste panel made to order, it may be interesting to some of you to learn how these tests were conducted. An empty class room was placed at our disposal. We used paired samples of chocolate milk prepared commercially for us in a local pasteurizing plant. We were particularly interested in evaluating the two qualities of degree of sweetness and of viscosity most acceptable to the consumer. For one test two bottles of chocolate milk, differing by 1.5% in sugar solids, were fitted with straws inserted through the cap and placed on top of each desk. Every bottle used carried a different identification number. A pencil and a brief questionnaire were distributed to each desk. The children of the fifth and sixth grades of the school were brought in during midmorning, room by room. It was explained to each group that we wished them to try both bottles of milk and determine if they liked one better than the other. Each child was asked to record either "No preference" or "Preference for # ?" If one was liked better for a particular reason the child was asked to state "Why." It was impossible for one individual to be guided in choice by another, since no two bottles were numbered alike.

The results of this series of tests were highly satisfactory. They were used as a guide in the final determination of the sweetness and viscosity of the chocolate syrup, which was subsequently manufactured commercially in large quantities. About a year later an occasion arose to check the validity of the sweetness determination through the use of a taste panel of children in an orphanage located in a distant city. We were gratified to find an 80 percent preference for the sweetness decided upon on the basis of the original children's panel.

In selecting a population sample one might confine their attention to present users of the particular type of product. Or, one might attempt to survey potential users as well. Or, more widely, a true cross-section of the population might be chosen. The question is just where shall the dividing line be drawn. Here it is pertiment to observe that choices confined to users only are apt to be misleading. Consider how useless such a panel would have been to Continental Foods seven years ago in determining preference for a new dry soup mix. Actual users at that time were comparatively few and confined to limited areas. Today the number of users of dry soup mixes is perhaps a hundred-fold and they are distributed throughout the United States, Canada, the West Indies and South America. Another aspect of a panel of users only is that average consumption varies widely between families. For certain food items such as canned chicken meat purchases may be three or four times as heavy in upper income families as in low income units. Vice-versa a small proportion of using families might account for 75 percent of the total consumption in the case of margarine. Therefore the average figures of users' experience may prove quite misleading unless carefully screened and proper weighting given to the preferences of the heavy users. This only emphasizes how carefully the sample used in a given panel must be chosen, and how selection will depend on the product and the objective.

Experience with mass taste panels has demonstrated that there exists a very definite tendency to prefer the food sample which is tasted first, whether the foods are consumed at different times or compared side by side. To overcome this difficulty it has become customary to ask one-half of the panel to sample one of a pair first, while the other half is requested to taste the other sample first. As additional precaution a subsequent query is preferably made to determine which one was actually tested first. The results of a typical taste panel reaction is given in the following choices between two samples of soup:

Sampled 1st	Preferred A	Preferred B	No Preference
A	36%	27%	37%
B	26%	36%	38%

This illustrates well the pitfalls that must be avoided in getting valid answers from a mass taste panel. Even with this reversal of first sampling one must scrutinize returns carefully to make certain that each group is equally represented.

Another difficulty one frequently experiences in the determining of choice in large taste panels is the high percentage of "no preference" votes by the respondents. In a "blind product test" such a lack of choice may mean either:

(a) The respondent could *not* detect a difference between the test products, or
(b) The respondent *could* detect a difference between the products, but had no preference for one over the other.

It is highly desirable to word the queries submitted to panel members in such a way that one is able to distinguish between these two types of "no preference" response.

The question of whether one should employ a personal interview technique on a door-to-door basis or resort to a "blind product test" by mail with a return questionnaire will be answered differently depending on circumstances. If sufficient funds are available to cover the much higher cost of the direct interview method it will generally prove preferable to the mailing technique. Unknown factors may sometimes cause a bias in preference selections which will invalidate results obtained by

mail. Personal discussion makes it possible to detect and weigh such factors as they may affect the preference expressed by the respondent.

The value of a "blind product test" with a mailed response has been considerably questioned in recent years because of the failure of certain mail polls to reflect a true cross-section of public opinion. One recalls how wide of the mark a Literary Digest poll of sentiment, prior to a national election, proved to be. Of course, the reason was that it failed to take into account a new factor which had entered into the determination of choice for a large segment of the electorate as a consequence of the Great Depression. However, the mail technique has slowly been winning its way back to favor with market research people as a result of further study of the factors which must be controlled in carrying out this type of consumer preference testing. In selecting a mass taste panel it is essential to determine that the individual participants are interested in food flavor and are willing to aid in this sort of research effort. No matter how carefully the panel is selected from the standpoint of being a true cross-section of the group to be reached, the validity of the response will be materially lessened if any considerable number of those included in the panel are not very interested in playing along. The composition of the panel should be so selected that it gives a proportional sampling by family sizes, by economic groups, by city sizes, and by geographical areas. It is generally held desirable not to select the group from among the known customers of one's own company. This is particularly true if the products to be judged may, at times, be improved variants of items which the company already has on the grocers' shelves. For this reason the tendency today is to leave the selection of the panels and the mechanics for conducting the mail preference study in the hands of advertising agencies or special market research organizations. If such outside groups are used to conduct the tests, competent persons from within the research organization of the company, should carry the responsibility for the frequent checking of questionnaires sent out and the panels selected, as well as the validity of references or conclusions drawn by the agency from the answers returned by the panel members.

Since the techniques of market research are not yet well agreed upon, it is highly desirable for the Research Department responsible for the development of the new item to give attention to the methods actually employed. In other words, it is necessary to research the techniques of research made use of in the mass taste panels. One method of doing so is to send out the same products on a "blind mail test" with questionnaires in which the queries are stated in different ways. For example, one questionnaire might ask, "How frequently do you serve spaghetti? Once a week? Once a month? Seldom? Never?" A better way of asking for the same sort of information would be, "Did you serve spaghetti to your family last week? If so, how often? At what meals? What members of the family were present?" The second form of query would supply a much more valuable guide to the particular eating habits of the respondents' families as regards spaghetti.

As a corollary to the need for careful representation of all groups on the taste panel it follows that a casual passer-by does not make a good judge for determining food preferences. In the first place the condition under which he samples the food is quite abnormal since most food is consumed in a dining room, or a restaurant, or a breakfast nook. Another objection is that no other food is served along with the sample, although normal usage for most food items would be as part of a meal. Frequently with this type of tasting no control samples are served. Thus, there is no opportunity for a true preference vote. A further objection arises from the fact that no control can be exercised on the grouping of the samplers. Depending on the location, one might find an over preponderance of housewives. In another area the group might be mostly office workers, etc.

There is a further caution about the selection of panels to be used as a guide to consumer preferences. Reliance on the opinion of an executive group, a research staff, a panel of office workers, or plant workers may lead to serious errors. For example, one soap company developed a new washing powder for the home which had so many plusses that everyone in the organization was exceedingly enthusiastic about it and became confident that the general public would share their enthusiasm. When efforts were made to market this greatly superior washing powder, Mrs. Housewife refused to buy it, because it was not white. She thought no washing powder could clean clothes satisfactorily unless it was snowy white. Our own company had a similar experience with a Black Bean Soup Mix. Practically everyone in the organization thought that this was a wonderful soup. Demonstrations of the new product in grocery stores were extremely disappointing, since at least half of the customers to whom samples of the soup were offered for tasting declined to do so. The color was so outside their experience with soups that they were not interested in even tasting the sample.

There are certain questions with regard to carrying out "blind product preference tests" with foods on which there remains a considerable difference of opinion. One of these is concerned with whether the questionnaire should be mailed separately to the respondents or whether it should accompany the sample. Our own method is to mail it with the samples.

In Figures 1 and 2 are shown the elements which comprise the mailed package received by the housewife. The mailing is done from a blind address which gives no indication of the source of the samples nor the company interested in them. Two identical unprinted bags are enclosed bearing identifying code numbers (in this case No. 63 and No. 79). Each bag is labelled with identical cooking directions. The return envelope for mailing in of questionnaires is addressed to a fictitious person. It is to be noted in Figure 2 that the questionnaire consists of two parts; the upper portion (qu. 1-7) to be answered by each person tasting the soup in the home, while the lower portion (qu. 8-9) is to be filled out by the housewife only. An explanatory letter outlines the method to be used in making the home test. Usually 4 questionnaires are included in each mailing on the assumption that there will usually be not more

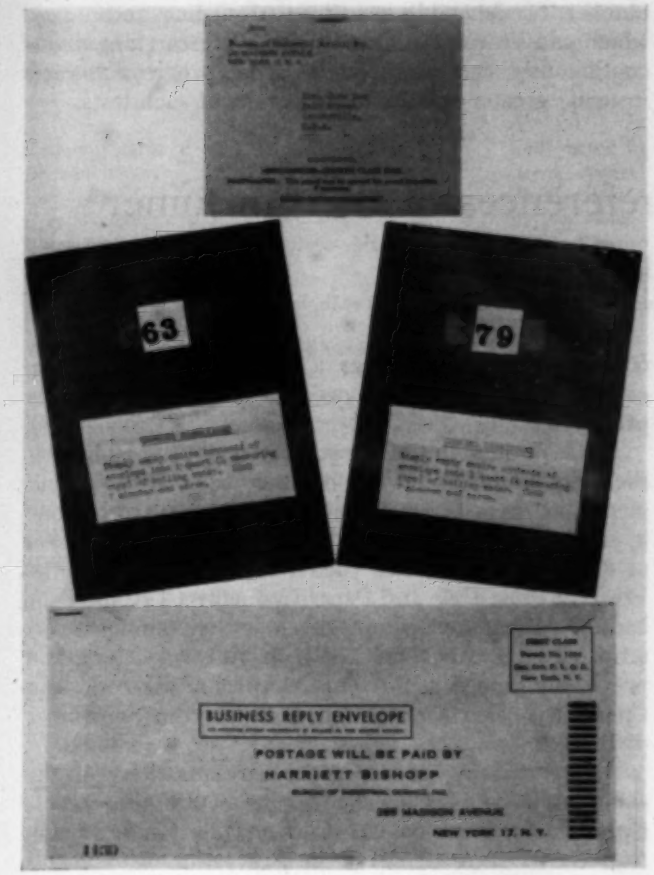

FIG. 1. Make-up of sample mailing.

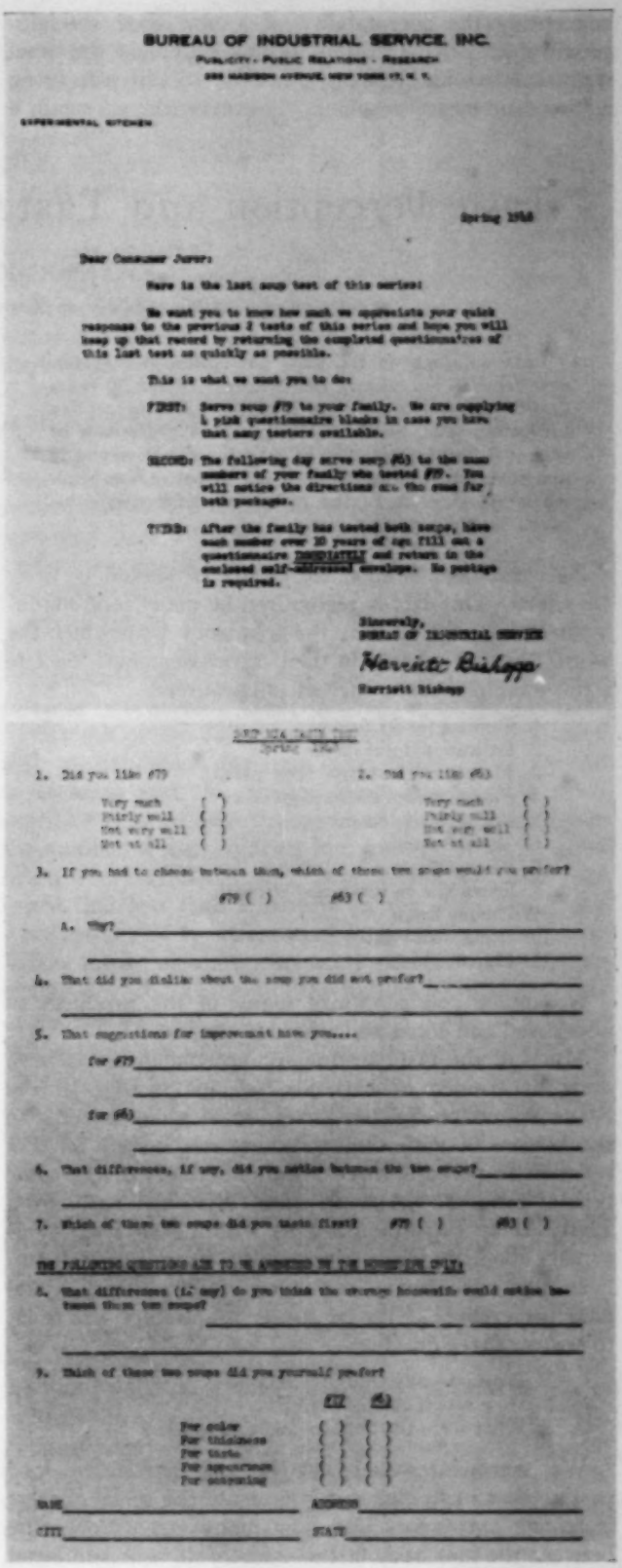
BUREAU OF INDUSTRIAL SERVICE, INC.
Spring 1948
Dear Consumer Juror:
Here is the last soup test of this series!
FIRST: Serve soup #79 to your family.
SECOND: The following day serve soup #63 to the same members of your family who tested #79.
THIRD: After the family has tested both soups, have each member over 10 years of age fill out a questionnaire IMMEDIATELY and return in the enclosed self-addressed envelope. No postage is required.
Sincerely,
Harriett Bishopp
1. Did you like #79
2. Did you like #63
Very much
Fairly well
Not very well
Not at all
3. If you had to choose between them, which of these two soups would you prefer?
#79 ( ) #63 ( )
4. What did you dislike about the soup you did not prefer?
5. What suggestions for improvement have you....
for #79
for #63
6. What differences, if any, did you notice between the two soups?
7. Which of these two soups did you taste first? #79 ( ) #63 ( )
8. What differences (if any) do you think the average housewife would notice between these two soups?
9. Which of these two soups did you yourself prefer?
#79 #63
For color
For thickness
For taste
For appearance
For seasoning
NAME
ADDRESS
CITY
STATE

FIG. 2. Details of questionnaire.

than 4 persons in the family sufficiently old to give reliable opinions concerning the acceptability of the samples. The latter portion of the questionnaire is designed to evaluate qualities which would be particularly noticed by the housewife.

We have found that the responses to this type of preference valuation with mass taste panels is quite valuable in guiding our development department in adjusting the food products to suit the general public. Usually each panel consists of 400 carefully selected families and a 60-65 percent response by families brings in from 500-800 completed questionnaires. In the opinion of our market research specialists this size of response is sufficiently large to give reasonable validity to the findings of the taste panel.

Finally, there remains the question of how to measure the taste acceptability of a food product different in type or kind from any now offered for sale. An example of this might be the corn chips known as Fritos which were introduced a few years ago. True, it was a fried chip and in that sense resembled potato chips. However, the peculiar flavor of the corn chip might or might not have proven acceptable to any considerable segment of the population. The current thinking on this type of taste-test is to send out several trial packages of the new specialty to a selected panel with an offer to furnish additional samples upon request. One might even go a step further and offer this group an opportunity to buy additional packages directly from the company. If the results of this type of a test indicate a very favorable acceptance of the product, a company would probably be justified in going directly to a small market sales test.

In summary, mass taste panels for measuring food preferences can be set up to provide reliable guidance

concerning the acceptability of a new food specialty provided proper precautions are taken to make the panel representative and to word questions so as not to bring a forced or biased response. However, there remain a number of debatable questions regarding techniques which can be employed and only by researching these continuously can we hope to make progress toward insuring greater validity in the results of such tests.

Taste Perception and Taste Preferences of the Consumer[a]

KATHERYN E. LANGWILL

Professor of Nutrition, College of Home Economics, Drexel Institute of Technology

Data obtained on the taste perception and preference for men and women between ages 17 and 30 years showed the women to have a higher taste perception for sweet, sour, bitter and salt. Taste preference of women differed from that of men for excessively salty and sour foods. The effect of pH of saliva was studied with reference to the ability to differentiate between the four basic tastes.

As consumers of food we all are or should be taste conscious. This fact is recognized by many food manufacturers as evidenced by the frequency with which the word "flavor" appears in their advertisements. To cite a few examples from current publications:

1. Famous for its flavor
2. Delicate natural flavor
3. Flavor and zest have been added
4. Flavor makes the meal go down
5. Purity, body, flavor
6. "Brisk" flavor
7. Fascinating artificial flavor
8. Extra rich in flavor and strength
9. Unique flavor
10. "Sing" with flavor
11. Flavor sealed

No doubt you recognize many of the products so advertised and could add others to the list.

Much of the taste testing for acceptability has been done by trained or carefully selected tasting panels. Some manufacturers, however, have gone directly to the housewife with their products and asked for her reaction to perhaps three different brands of the same type of product. (A symposium edited by Washington Platt "What the Manufacturer Can Learn from Consumers about Foods"—March 1941, Food Industries.)

In this preliminary report on taste perception and taste preferences of the consumer, an attempt was made to answer three questions.

1. Why was this study undertaken?
2. How was it carried out?
3. What were the findings and conclusions?

We were interested not in any particular food product but in finding out how acute the sense of taste is among consumers and how many can differentiate between the four basic tastes—sweet,salt, sour and bitter —at concentrations above liminal. Further than this, we wished to find out if there was any correlation between the pH of the saliva of an individual and the ability to taste. While collecting this data, it seemed worthwhile to also investigate the preferences of the consumer: that is whether a slightly, moderately, or excessively sweet, salty or sour food product was preferred.

It was decided to test the sensitivity of taste by having the individuals taste pieces of filter paper: one a blank piece, one dipped in a solution of sugar (sucrose), one in salt, another in citric acid, and the last in a solution of quinine sulfate. This idea was not original as the West Virginia Pulp and Paper Company (Tyrone, Pa.) had given out cellophane envelopes containing small strips of filter paper, marked with different colors, and previously dipped in the four solutions at the American Chemical Society Convention in Chicago in September of 1946.

Before arriving at the exact concentrations of the solutions to be used for the dipping of the filter paper, a preliminary test was carried out on twenty-nine women from the Welfare Group of the Federation of Women's Clubs in Delaware County. Of this group only six were able to differentiate between the four basic tastes. They commented that it was fairly easy to distinguish sweet and bitter but that salt and sour were too weak. After the meeting one of the older women told me confidentially that she could not taste anything on the slips of filter paper but that it was probably due to the fact that she had both upper and lower dentures.

The suggestion of this group was followed and the concentration of both the salt and acid solutions was increased. The concentrations finally employed were:

Sugar (sucrose)	0.0771 Molar
Salt (NaCl)	0.1539 Molar
Sour (Citric acid)	0.02601 Molar
Bitter (Quinine sulfate)	0.001349 Molar

Large pieces of filter paper (22″ x 28″) were cut into four small pieces and each was dipped in a different solution. The papers were carefully drained and then laid on a smooth porcelain tray to dry. The papers were marked later with colored crayons and then cut into strips 2″ long and ⅜″ wide. Five slips of filter paper were put into each cellophane envelope—one blank and one for each of the four basic tastes. A different color was used to mark each piece of filter paper which meant that it was possible to set up five different color arrangements. Therefore, only every fifth person would actually be tasting a set of papers where the color and taste were the same. The papers to which the cellophane envelope was attached were numbered to indicate the color arrangement. To illustrate: if 1 appeared in the number, then the piece of filter paper marked with a yellow crayon was the blank; if 2 appeared in the number, the

[a] Presented before the Eighth Annual I. F. T. Convention, Philadelphia, Pa., June 8, 1948.

blank was green; if 3 appeared in the number, the blank was brown; and so forth. Actually the following code was employed.

1	3	5
Yellow—blank	Brown—blank	Red—blank
Brown—sweet	Blue—sweet	Green—sweet
Red—salt	Green—salt	Blue—salt
Green—sour	Red—sour	Yellow—sour
Blue—bitter	Yellow—bitter	Brown—bitter

2	4
Green—blank	Blue—blank
Yellow—sweet	Red—sweet
Brown—salt	Yellow—salt
Blue—sour	Brown—sour
Red—bitter	Green—bitter

The individual taking the tasting test was asked to check the paper as to sex, age group, and preference in relation to degree of sweetness, saltiness and sourness of foods. Samples of saliva were collected in sputum bottles which were tightly corked until the pH was determined by use of a Beckman pH meter (model G with glass electrode). This was done within an hour after the collection of the sample.

Now a word about the participants in this study. About half of the women tested were student nurses from the University of Pennsylvania who were taking their first college course in Foods and Nutrition. One quarter was made up of freshmen in the College of Home Economics at Drexel Institute of Technology and most of them were taking their first course in Foods Preparation. The other quarter included juniors and seniors at Drexel who had had three or more courses in Foods.

It was through the courtesy of the Chemistry Department at Drexel that we were able to contact the men students. The chemistry professors were willing to allow the last 15 minutes of the class hour for the giving of the tests. The majority of the men students were freshmen but we did reach over fifty upper classmen. In every case, the tests were given at the end of the class hour so that, to the best of our knowledge, nothing had been eaten for at least forty-five minutes. Therefore, it was felt that previously consumed food would have no effect on the pH of the saliva sample collected.

Samples of saliva were collected from 262 women and 247 men making a total of 509. Actually we were interested in only 499 cases (257 women, 242 men) because it was decided to limit our study to students under thirty years of age. This eliminated one man and four women. The other five students (4 men and 1 woman) were dropped from the study because the pH of the saliva was extremely low—5.1 and 5.4. We had hoped to be able to obtain a second sample of saliva from each of these individuals but this was possible only in the case of the woman. The pH of her second sample of saliva was 6.1. On questioning the student to learn if there was any change in the condition of her mouth since giving the first sample, she told us that an open cavity had been closed with a temporary filling. It was assumed, therefore, that an abnormal condition existed in the mouths of the other students whose saliva gave a pH below 5.5.

From a study of the preferences recorded by the participants in this experiment, some interesting facts were revealed. As might be expected, over 50 percent of both men and women preferred their foods only moderately sweet and salty. (Sweet, M—66.5, W—70.2; Salt, M—55.2, W—52.0). The same percentage (16.3) of individuals preferring foods excessively sweet was observed for men and for women, but fewer women than men preferred only slightly sweet food (W—13.5, M—17.2). A higher percentage of women than men preferred excessively salty foods (W—21.0; M—15.8) but only 2 percent more men than women preferred just slightly salty foods.

When we examined the preferences in relation to sourness, we found that more than twice as many women (11.9%) as men (5.4%) preferred foods excessively sour. The same number of women (111) liked foods both moderately and slightly sour. With men, the picture was quite different. Fifty-seven percent (57.2%) preferred only slightly sour foods and 37.5 percent chose moderately sour.

In analyzing the results of the tasting test, it was found that 113 of the 242 men or 46.7% were able to differentiate between the four basic tastes at the concentrations employed. One hundred and ninety-eight (198) out of the 257 women students or 77.0% were able to distinguish the four basic tastes. This seemed to indicate that the women were considerably more sensitive to taste than the men. When we broke down the number of men students into two age groups—those below 20 years of age and those 20 years or over—we found that less than 2 percent in the older age group were better able to differentiate between the basic tastes. When the women students were divided into the two age groups, 78.9 percent of the women 20 or more years of age and 73.3 percent of the women under 20 years of age were able to distinguish the basic tastes. Therefore, the amount of training in Foods may have some slight influence on the student's ability to discriminate when tasting.

On further analysis of our figures, it was found that, of the 129 men who were unable to distinguish correctly between the four basic tastes and the blank piece of filter paper, 70 confused two flavors, 29 confused 3, 24 confused 4 and only 6 men were wrong on all five counts. The two combinations of tastes or flavors which were missed an equal number of times by the 70 men who confused only two of the pieces of filter paper were "salt and sour" and "blank and sour." Of the men who judged incorrectly two or three of the flavors, the greatest number of them had saliva of a pH between 6.8 and 7.1. Of those who missed four or five of the flavors, the pH of the saliva samples was more widely distributed and did not show a significant concentration as near the neutral point.

Practically the same results held for the women who were unable to differentiate between the four basic tastes and the blank piece of filter paper. Forty-one confused 2 flavors, 8 confused 3, 9 confused 4 and only one judged all incorrectly. The two combinations of flavors which were missed an equal number of times by the women who confused only two flavors were "salt and sour" and "sour and bitter." Again it was found

that the pH range which included the greatest number of women who were unable to differentiate correctly between two, three or four of the flavors was between 6.8 and 7.1.

In an attempt to show graphically the relationship

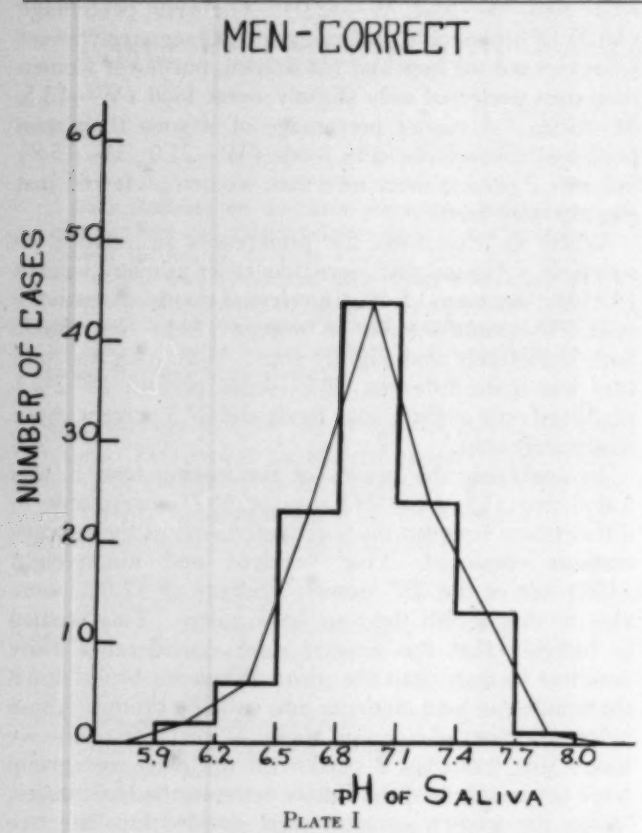

PLATE I

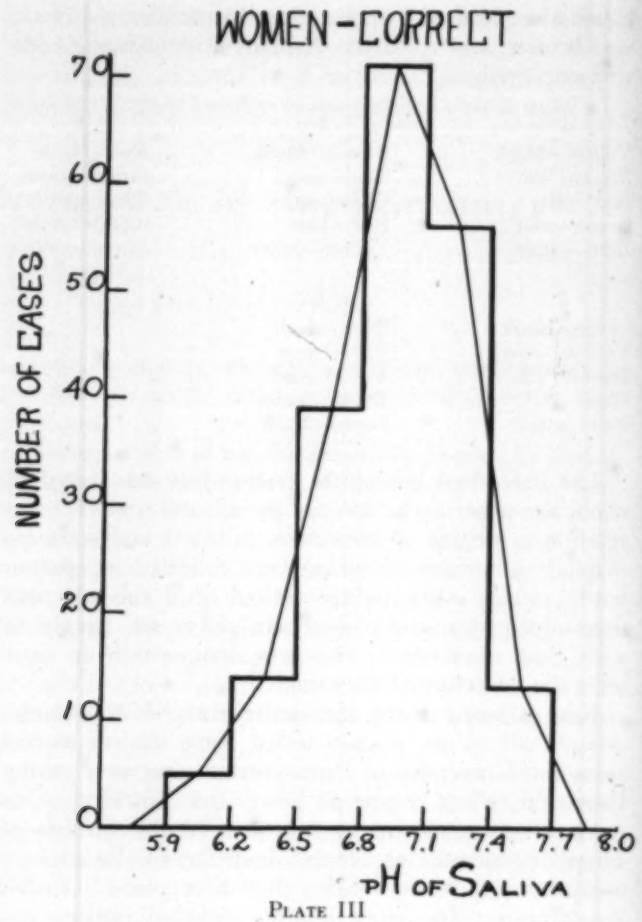

PLATE III

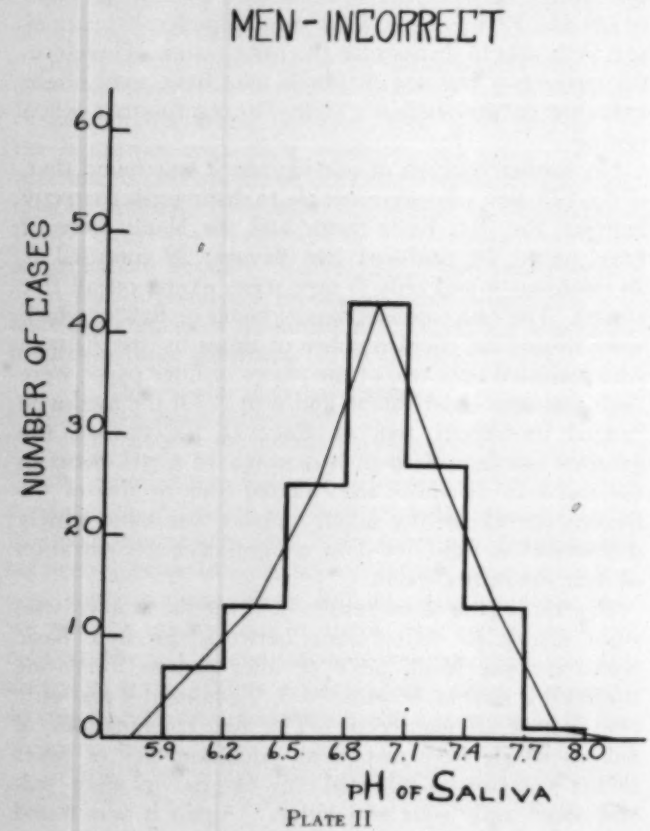

PLATE II

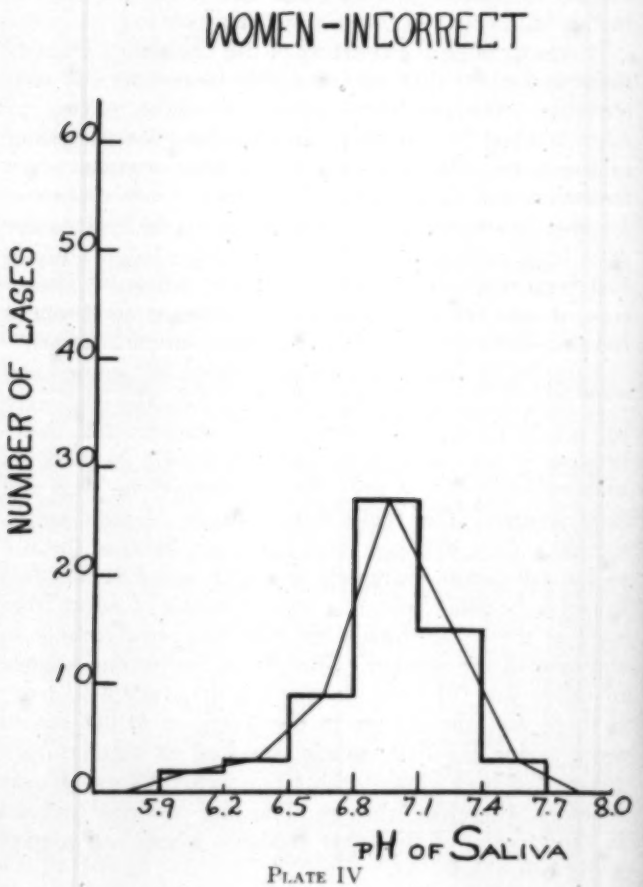

PLATE IV

between pH of saliva and ability to taste, four histograms (Plates I-IV) were prepared. When we compared the histogram of the men who were able to differentiate correctly between the four basic tastes and the one of those who were not able to do so, we found that in both instances the greatest number of cases fell within the pH range of 6.8 and 7.1. This condition also existed among the women tasters as will be noted by examining the two histograms prepared from the results of the tests on women. Again in both instances, the greatest number of cases fell between the pH range of 6.8 and 7.1. This indicated that apparently the pH of the saliva did not influence the individual's sensitivity to the four basic tastes at comparately low concentrations.

A graph (Plate V) was made plotting the pH on the horizontal axis and percentage correctly distinguishing the basic tastes on the vertical axis. This showed again the fact that men were less discriminating in their taste.

Comments made by some of the participants in the study may be of interest. One of the young women said that she had had severe sinus trouble for the past year and could taste nothing on the filter papers. A young man told me that he had been using nose drops for his cold so he doubted if he could taste very well. He passed in a perfect score. The men who had been in service reported they could not taste well after tasting the bitter piece of filter paper.

In summary, the conclusions derived from this study of taste perception and taste preferences of the consumer and applicable only to a specific age group—approximately 17 to 30 years of age—were the following:

1. Over 50 percent of both men and women preferred moderately sweet and salty foods.
2. More women than men preferred excessively salty and sour foods.
3. Over 50 percent of the men liked slightly sour foods.
4. The pH of the saliva did not appear to have any influence on the ability of an individual to differentiate between the four basic tastes since the greatest number of correct and incorrect answers were submitted by individuals whose saliva showed a pH of between 6.8 and 7.1.
5. Women showed a greater sensitivity of taste in distinguishing between the four basic tastes—sweet, salt, sour and bitter.

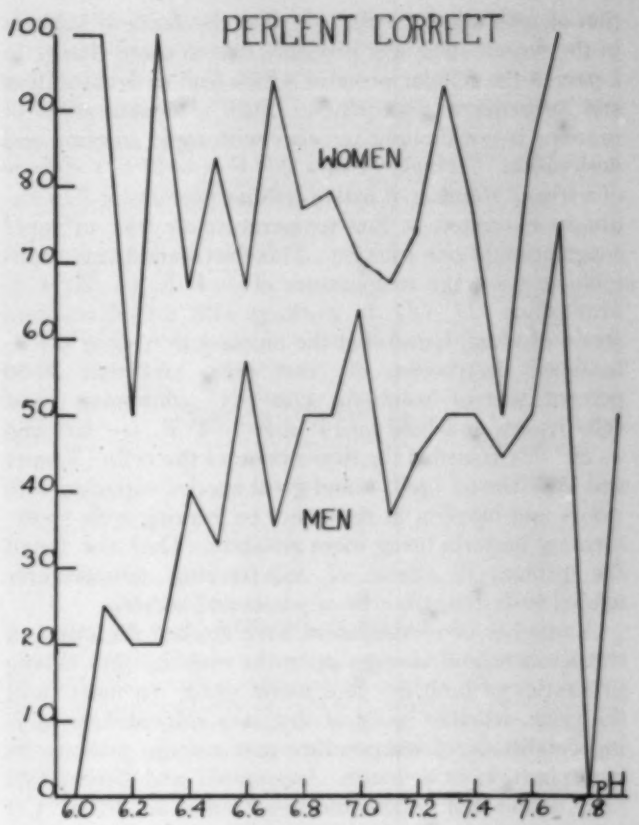

PLATE V

Fermentation Activity and Survival of Yeast in Frozen Fermented and Unfermented Doughs

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Data are presented relative to the survival of yeast at sub-freezing temperatures. Experimental results and information pertinent to the viability of baker's yeast, Saccharomyces cerevisiae, in frozen doughs, as well as the possible influence of the freezing rate upon the biological activity of yeast, are also discussed.

Introduction

It has been a general belief that micro-organisms tend to die out when held at below-freezing temperatures. This view is supported by Berry *(2)* when he speaks about many kinds of bacteria failing to grow at 32° F. (0° C.), and all types of micro-organisms being suppressed and tending to die out at approximately 15° F. (— 9.5° C.). The literature reports growth of various species of micro-organisms at sub-freezing temperatures, however, there is little indication of microbial growth occurring below 14° F. (— 10° C.), Berry and Magoon *(5)*, Smart *(13)*, Haines *(9)*, and Berry *(3)*. The occurrence of some micro-organisms showing this ability to grow at low temperatures is probably the result of several factors, such as species or strain resistance to low temperatures, humidity and oxygen relationships, rate of freezing, pH of substrate, sub-freezing storage temperature, and composition of the material containing the micro-organisms. Although many observers believe that the absence of sufficient liquid water prevents metabolism and growth of micro-organisms, evidence to the contrary has been supplied by the investigators previously referred to. Rapid freezing with desiccation has been shown to be a very successful method of preserving bacterial cultures. Since Haines *(8, 7)*, did not find the rate of freezing to have an effect on the propor-

tion of cells killed, he thought that the death of bacteria in the frozen state was probably due to some change in a part of the cellular proteins which lead to denaturation and subsequent flocculation. Such a denaturation of proteins is not thought to occur with rapid freezing and desiccation. Haines found a 28° F. (— 2° C.) storage of a frozen solution of native cellular proteins of *P. aeruginosa* extracted at low temperature to lead to rapid coagulation of one fraction. This flocculation was negligible at a storage temperature of — 4° F. (— 20° C.). McFarlane *(11, 12)*, in working with a cold resistant strain of yeast, found that the increase in hydrogen ions hastened destruction of yeast cells, and that 30-50 percent sucrose solutions with pH5 containing yeast cells frozen and held at 14° and — 4° F. (— 10° and — 20° C.) retarded the destruction of the cells. Tanner and Williamson *(16)*, found great species variation with yeasts and bacteria in resistance to freezing with spore-forming bacteria being more resistant. They also found the prolonged action of sub-freezing temperatures tended to destroy the cells of yeasts and bacteria.

A number of investigators have studied the effect of temperature and storage upon the viability and baking properties of both dry and moist yeast. In most cases the yeast, whether moist or dry, was subjected to varying conditions of temperature and storage prior to its incorporation in a dough. Iwanowski and Brezezinski *(10)*, found that yeast could be stored at 32° F. (0° C.) for two to three months and not show marked deterioration. When the yeast was stored at 56° F. (13.5° C.) for about two weeks, there were 10 to 20 percent dead cells present and storage at 72° F. (22° C.) for one week showed the presence of about 20 percent of dead cells. They concluded that storage of the yeast at these temperatures and periods of time did not produce marked changes in its physiological state with the exception of loss of ability to bud when stored at 72° F. (22° C.). Cook and Malloch *(6)*, found little change in the gas producing ability of yeast stored at 0° F. (— 18° C.) up to ten days. Staiger and Glaubitz *(14)*, stored yeast at 14° to — 13° F. (— 10° to — 25° C.) for one to four days and then thawed the yeast at room temperature and 41° F. (5° C.) respectively. Very little change in properties was noticed and the baking and keeping qualities of the yeast, the nitrogen content, and biological appearance remained practically normal. Bailey, Bartram, and Rowe *(1)*, stored compressed yeast, which had previously been packed with dry ice for two days, but not frozen, along with fresh compressed yeast at temperatures of 0°, 20°, 30°, and 45° F. (—18°, — 6.5°, — 1° and 7° C.) for three months. Microscopical, pH, and baking tests were made at the beginning and the end of one, two, and three months' storage. The yeast that had been packed with dry ice deteriorated more rapidly than the fresh yeast stored under the same conditions of time and temperatures. The frozen yeast became mushy after it was thawed. The storage temperature of 30° F. (— 1° C.) was considered most suitable since the yeast did not freeze nor lose its normal consistency, and bread made from this yeast was fully equal to that made with yeast stored at the other temperatures used in their experiments. They found that the temperature of dry ice —109° F. (— 78.5° C.), injured yeast in 24 hours and subsequent storage below freezing increased the amount of deterioration. Thiessen *(17)*, found compressed yeast to be well preserved for from one to three months by freezing at 19° F. (— 7° C.) and that the yeast resumed almost normal biological activity when mixed into a dough and placed under favorable environmental conditions.

Sunderlin, Collins, and Acheson *(15)*, conducted frozen roll dough experiments in which the dough, after one rising and punching was packed into containers, sealed, and put through the "quick freeze" at — 10° F. (— 23.5° C.), then placed in the frozen locker and held at 0° F. (— 18° C.). Tests showed that the yeast cells were not destroyed by this process. Up to a six week frozen storage period, the roll dough, when thawed, allowed to rise, molded, proofed, and baked, made acceptable rolls. When the rolls were stored for a longer period, "off flavors and odors" developed.

Experimental Procedure and Results

In the preliminary work with frozen bread sponge dough, it was found that fermented sponges could only be kept frozen for a short time at — 10° F. (—23.5° C.) (3 days to 1 week) without deleteriously affecting the yeast. As the freezing storage interval was increased the sponge became increasingly lacking in fermentative activity. Sponge doughs which had been frozen and held at — 10° F. (— 23.5° C.) without any prior fermentation period showed a greater amount of fermentative activity than similarly handled fermented doughs after one month's storage. In all cases the sponges were packaged in sealed cardboard quart containers wrapped with cellophane, prior to freezing and subequent storage. When removed from storage, both the fermented and unfermented sponge doughs were allowed to thaw out at room temperature and then remixed with the remaining dough ingredients. After remixing, the doughs were given a pan proof and then baked.

Some further preliminary bake tests were run using both dry yeast and compressed yeast which had been cultured under abnormal conditions. Both yeasts were cultivated in a broth containing 4 percent maltose, 1 percent peptone, and 0.1 percent ammonium chloride, and while vigorous and active were transferred to a deficient nutrient broth similar to that of Gorodkowa's Sporulating Agar Medium, except for the elimination of the agar. The yeasts were held in the deficient medium until the cells ceased to reproduce and internally showed a large amount of granular reserve material and thick cell walls but devoid of spores. The yeast was then recovered by centrifugation and stored at 35° F. (1.5° C.) in a plastic condition. Bread baked with these special prepared yeasts which had been stored for one month at 35° F. (1.5° C.) was comparable to bread prepared from fresh commercial dry and compressed yeasts. Although the abnormal cultured yeasts were active when introduced into a sponge dough prior to freezing, subsequent freezing and storage of the unfermented doughs containing these yeasts at — 10° F. (— 23.5° C.) for one month rendered them practically lifeless and incapable of fermentation activity.

Some early work had also been done in refrigerating straight fermented doughs at 40° F. (4.5° C.) which had been packaged in glass containers with the clamping type covers. Storage of these doughs for two weeks was detrimental to the yeast, since even fortification with approximately one percent fresh yeast, prior to proofing,

produced a very poor loaf of bread with a sour aroma and taste. Later, a simple fermented sponge was flattened out in a shallow pan, wrapped in cellophane, and stored at 35° F. (1.5° C.) After a storage period of five weeks, the sponge still had life and, although the pan proof was extended twenty-five minutes beyond that of the control, no additional fresh yeast was added. The loaves had good volume with a slight sour odor and off taste.

The principal part of this work with frozen doughs is concerned with several series of roll doughs which were frozen and stored under varying conditions.[a] The roll dough formula used was as follows:

Patent flour	100 lb.
Sugar	12½ lb.
Shortening	12½ lb.
Whole eggs	5 lb.
Powdered skim milk	6 lb.
Water	64 lb.
Salt	1¾ lb.
Yeast	3 lb.
Yeast food	½ oz.

These series of roll doughs were made and handled in the following manner:

Series No. 1—Unfermented dough frozen and stored at —10° F. (—23.5° C.). The rolls were formed, placed in a pan, covered with a cardboard lid, wrapped with cellophane, placed in a cardboard box, frozen, and stored.

Series No. 2—Unfermented dough frozen and stored at 0° F. (—18° C.). These rolls were handled in a manner similar to that in series No. 1, except that the pans were individually placed on the metal plates in the freezing cabinet instead of being further covered by a cardboard box.

Series No. 3—Fermented dough frozen and stored at —10° F. (—23.5° C.). Except for a fermentation period of approximately 3 hours prior to freezing, the rolls were handled similarly to those in Series No. 1.

Series No. 4—Fermented dough frozen and stored at 0° F. (—18° C.). The rolls were fermented approximately 3 hours prior to freezing and handled similarly to those in Series No. 2.

Freezing-rate curves of two different Series (Series No. 1 and 2) roll doughs were recorded by using a Leeds & Northrup Potentiometer and extending the thermocouple leads into the center of the rolls (Figure 1). In addition the freezing-rate curve was run on an unfermented panned roll dough in which the pan was placed directly on a metal rack in the —10° F. (—23.5° C.) freezing cabinet (Figure 1).

The frozen doughs were stored at temperatures of 0° and —10° F. (—18° and —23.5° C.) for increasing periods of time. As each pan of roll dough was removed from the freezing cabinet, one single roll was removed aseptically for a yeast count. The remaining rolls were placed in the fermentation cabinet held at 86° F. (30° C.) and 85 percent relative humidity and allowed to proof to a predetermined height which had been established with unfrozen control bakes. The interval of time from freezer to oven was recorded. Each set of rolls was baked for 20 minutes at 380° F. (193.5° C.). Following baking, the rolls were evaluated as to volume, aroma, taste, texture of crumb, etc. (Tables 1, 2, 3, 4, and 5).

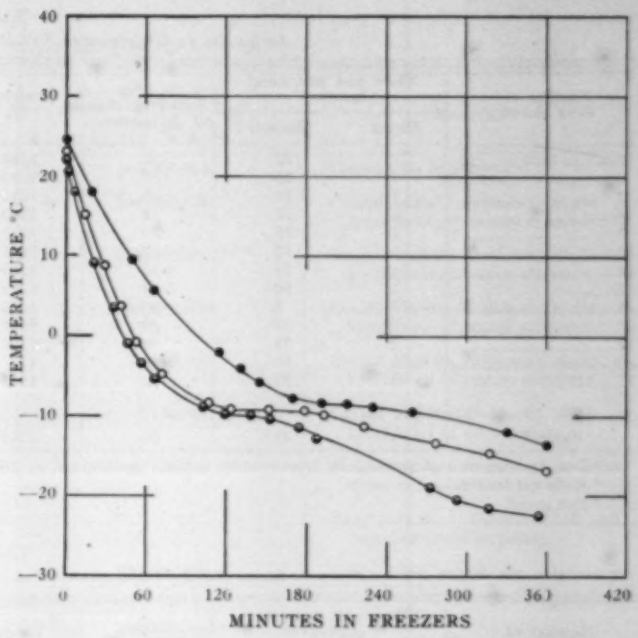

FIG. 1. Cooling rates of unfermented roll doughs in —18°C. and —23.5°C. freezing cabinets. ● = pans of roll doughs placed in cardboard box in —23.5°C. cabinet; ◓ = pans of roll doughs placed on metal rack in —23.5°C. cabinet; ○ = pans of roll doughs placed on metal rack in —18°C. cabinet.

The yeast counts were run on each set by weighing 10 grams of the roll, that had been taken for this use, into 92 cc. of sterile 0.85 percent sodium chloride solution and mixing in a Waring Blendor for three minutes. The suspension was found to have a volume of 100 cc., exclusive of foam. Further dilution of the dough suspension was made to give yeast counts which ranged between 30 and 300 colonies per plate. A 4 percent maltose and 1 percent peptone nutrient agar was used with the pH adjusted to 3.75 prior to pouring the plates. Yeast counts were taken after incubating the plates for 72 hours at 86° F. (30° C.) in a chamber with the relative humidity adjusted to 85 percent. Even though the Waring Blendor did break up the dough into very small particles, it was realized that the counts would tend to be low due to clumping of the yeast cells on and within the dough particles. The high dilutions used in order to have plates showing 30 to 300 colonies were advantageous, since they culled out the contaminating molds and wild yeasts normally present in the various ingredients used for preparing roll doughs.

Also included in this report is an experiment comparing the baking qualities of three different commercial brands of compressed yeast which had been frozen. Three fresh one-pound samples of these yeasts were frozen and stored at —10° F. (—23.5° C.) for 7 months. Each sample had been wrapped in cellophane with an outer covering of wrapping paper. Following storage, sections were taken from the exterior of the cakes to one-fourth inch inward and also the center portion to one-half inch outward. These samples were allowed to thaw to room temperature and then used for making bread. In one case the pan proof of the doughs containing the prefrozen yeast was allowed the same time in-

[a] It was felt that the panned roll doughs, because of their smaller size, would offer a better medium for quick freezing than the previously mentioned bread doughs. The formula cited is similar to the one used by Sunderlin, Collins, and Acheson *(15)* in their successful freezing experiments with roll doughs.

TABLE 1

Series No. 1—Unfermented Roll Dough Frozen and Stored at — 23.5° C.

Number of days stored	Thaw and pan proof interval [1]		Baking Time Minutes	Volume cc.	Yeast cells per gram of dough; Standard plate count 30° C. for 72 hr. at 85% R. H.	Remarks
	Hours	Minutes				
1	1	47	20	1210	290,000,000	Comparable to control
2	1	35	20	1295	270,000,000	Comparable to control
3	1	30	20	1215	259,000,000	Comparable to control
4	1	35	20	1280	207,000,000	Comparable to control
7	1	35	20	1285	264,000,000	Slightly more open grain
10	1	55	20	1295	210,000,000	Slightly more open grain
14	1	52	20	1215	200,000,000	Slightly more open grain
21	1	50	20	1285	19,000,000	Slightly more open grain
28	2	8	20	1270	12,000,000	Slightly more open grain
37	2	20	20	1160	12,000,000	Slightly more open grain
51	2	55	20	1190	<1,000,000	Coarser grain
66	3	10	20	1170	<100,000	Coarser grain plus surface rupture
75	3	27	20	1115	<100,000	Very coarse grain, dark crumb, and surface rupture
Control [2]	1	35 [3]	20	1325	306,000,000	Taste, color, crumb, etc. satisfactory

[1] Doughs thawed and proofed in fermentation cabinet maintained at 30° C. and 85% R. H.
[2] Rolls not frozen.
[3] Pan proof.

TABLE 2

Series No. 2—Unfermented Roll Dough Frozen and Stored at — 18° C.

Number of days stored	Thaw and pan proof interval [1]		Baking Time Minutes	Volume cc.	Yeast cells per gram of dough; Standard plate count 30° C. for 72 hr. at 85% R. H.	Remarks
	Hours	Minutes				
4	1	48	20	1280	215,000,000	Comparable to control
6	1	45	20	1275	206,000,000	Comparable to control
12	2	3	20	1265	186,000,000	Comparable to control
20	2	35 [2]	20	1370	210,000,000	Comparable to control
28	2	15	20	1280	135,000,000	Comparable to control
38	2	15	20	1305	3,000,000	Comparable to control
61	2	50	20	1260	<1,000,000	Comparable to control
75	3	18	20	1215	<100,000	Coarser grain and slightly darkened crumb
Control [3]	1	35 [4]	20	1240	225,000,000	Taste, color, crumb, etc. satisfactory

[1] Doughs thawed and proofed in fermentation cabinet maintained at 30° C. and 85% R. H.
[2] Overproofed. Rolls accidentally proofed to a greater height than standard control.
[3] Rolls not frozen.
[4] Pan proof.

TABLE 3

Series No. 3—Fermented Roll Dough Frozen and Stored at — 23.5° C.

Number of days stored	Thaw and pan proof interval [1]		Baking Time Minutes	Volume cc.	Yeast cells per gram of dough; Standard plate count 30° C. for 72 hr. at 85% R. H.	Remarks
	Hours	Minutes				
1	1	33	20	1380	240,000,000	Comparable to control
2	1	45	20	1295	201,000,000	Comparable to control
3	1	49	20	1330	215,000,000	Comparable to control
4	1	40	20	1295	185,000,000	Comparable to control
7	1	42	20	1235	187,000,000	Comparable to control
11	2	15 [2]	20	1150	48,000,000	Slightly darker crumb and breakdown of crumb structure
14	2	15	20	1225	32,000,000	Slightly darker crumb and breakdown of crumb structure
21	3	26 [2]	20	1165	20,000,000	Crumb darkness and breakdown of structure increased
29	5	.... [2]	20	1195	56,000,000	Crumb darkness and breakdown of structure increased
85	5	10 [2]	20	850	.....	Very coarse grain, heavy breakdown of grain structure, and very pale crust
Control [3]	..	55 [4]	20	1275	251,000,000	Taste, color, crumb, etc. satisfactory

[1] Doughs thawed and proofed in fermentation cabinet maintained at 30° C. and 85% R. H.
[2] Frozen rolls raised, indicating longer floor time interval prior to freezing.
[3] Rolls not frozen.
[4] Pan proof.

terval as the control dough containing unfrozen fresh yeast, while in the other case the pan proof time was extended so that the loaves would have a prebaking height comparable to the control. The baked loaves were compared against the control for volume, aroma, taste, color, crumb texture, etc. (Table 6).

In addition to the experimental work already cited in this report, Table 7 is shown listing the survival of vari-

TABLE 4

Series No. 4—Fermented Roll Dough Frozen and Stored at — 18° C.

Number of days stored	Thaw and pan proof interval [1]		Baking Time Minutes	Volume cc.	Yeast cells per gram of dough; Standard plate count 30° C. for 72 hr. at 85% R. H.	Remarks
	Hours	Minutes				
4	1	30	20	1275	206,000,000	Comparable to control
6	1	34	20	1235	198,000,000	Crumb slightly darkened; slight breakdown of crumb structure
12	1	53	20	1240	206,000,000	Crumb slightly darkened; slight breakdown of crumb structure
20	2	42 [2]	20	1300	234,000,000	Crumb slightly darkened; slight breakdown of crumb structure
28	2	38 [2]	20	1240	85,000,000	Crumb slightly darkened; slight breakdown of crumb structure
38	2	35	20	1225	<100,000	Crumb slightly darkened; slight breakdown of crumb structure
61	5	10 [3]	20	1035	<100,000	Coarser grain and increase in breakdown of crumb structure
75	5	10	20	910	.....	Very pale crust, darker crumb and ruptured grain structure
Control [4]	..	55 [5]	20	1285	225,000,000	Taste, color, crumb, etc. satisfactory

[1] Doughs thawed and proofed in fermentation cabinet maintained at 30° C. and 85% R. H.
[2] Overproofed. Rolls accidentally proofed to a greater height than standard control.
[3] Frozen rolls raised, indicating longer floor time interval prior to freezing.
[4] Rolls not frozen.
[5] Pan proof.

TABLE 5

Effect of Cooling Rate on Unfermented Roll Doughs Frozen and Stored at — 18° and — 23.5° C.

Modification	No. of days Stored	Thaw and pan proof interval [1]		Baking Time Minutes	Volume cc.	Remarks
		Hours	Minutes			
Pans of roll doughs placed in cardboard box in — 23.5° C. cabinet	75	3	27	20	1115	Very coarse grain, dark crumb, and surface rupture
Pans of roll doughs placed on metal rack in — 23.5° C. cabinet	75	3	2	20	1295	Slightly darker crumb showing more open grain than controls
Pans of roll doughs placed on metal rack in — 18° C. cabinet	75	3	18	20	1215	Coarser grain and slightly darker crumb than controls
Control No. 1—Rolls not frozen	—	1	35 [2]	20	1325	Taste, color, texture, etc. satisfactory
Control No. 2—Rolls not frozen	—	1	35 [2]	20	1240	Taste, color, texture, etc. satisfactory

[1] Doughs thawed and proofed in fermentation cabinet maintained at 30° C. and 85% R. H.
[2] Pan proof.

ous yeast strains frozen and stored at — 10° F. (— 23.5° C.). These strains were originally purified by diluting, reculturing, and then freezing and storing at —10° F. (—23.5° C.) in 0.85 percent sodium chloride with a pH of 5.2. Counts were made at different intervals of storage and thus the cultures were, in all cases, repeatedly subjected to alternate freezing and thawing. The experimental grown spore yeast was derived from a sample of dry yeast (See Table 7, Strain No. 2) which sporulated readily when transferred from an active growing state to Gorodkowa's Sporulating Agar. Actual photographs of the asci containing spores, from this yeast, are shown in Figure 2. The abnormal cultured yeasts (Strains No. 3 and 4, Table 7) were the same as the special prepared yeasts previously mentioned in this paper. As shown in Table 7, all counts were made after an incubation period of 3 days at 86° F. (30° C.), using a 4 percent maltose and 1 percent peptone nutrient agar and adjusting the pH to 3.75 before pouring the plates. The original yeast spore counts were based on a percentage of the total plate count, this percentage having been determined by noting the amount of sporulation for each sample shown in approximately 25 microscopic fields. Consequently

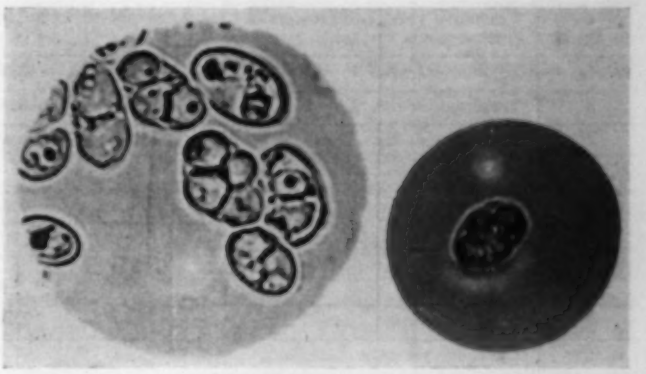

FIG. 2. Experimental grown spore yeast from dry yeast.
a. Several asci showing sporulation. x2000.
b. Single ascus showing 4 spores. x1300.

spore counts for the first few weeks of storage were probably on the high side, due to the survival of an appreciable number of vegetative cells during this period.

Discussion

Little success was shown with bread sponge doughs frozen and held at —10° F. (— 23.5° C.) where storage

TABLE 6

Fermentation Activity of Commercial Yeasts Frozen 7 Months at — 23.5° C.

Yeast Sample [1]	Condition of Yeast when thawed	Sponge fermentation time [2] Hours	Pan proof [2] time		Volume cc.	Baking Test Remarks
			Hours	Minutes		
No. 1—Interior Section	Soft but retained shape	3	1	15	1790	Comparable to control except for lower volume and compactness
No. 1—Interior Section	Soft but retained shape	3	2	5	2200	Comparable to control
No. 1—Exterior Section	Soft but retained shape	3	1	15	1855	Comparable to control except for lower volume and compactness
No. 1—Exterior Section	Soft but retained shape	3	2	5	2275	Comparable to control
No. 2—Interior Section	Plastic—loss of shape	3	1	15	1805	Comparable to control except for lower volume and compactness
No. 2—Interior Section	Plastic—loss of shape	3	2	5	2325	Comparable to control
No. 2—Exterior Section	Plastic—loss of shape	3	1	15	1990	Comparable to control except for lower volume and compactness
No. 2—Exterior Section	Plastic—loss of shape	3	2	5	2350	Comparable to control
No. 3—Interior Section	Fluid	3	1	15	1675	Very poor volume and weakly fermented product. Increase in proof time not effective.
No. 3—Exterior Section	Fluid	3	1	15	1690	Very poor volume and weakly fermented product. Increase in proof time not effective.
Control—Unfrozen fresh compressed yeast	.....	3	1	15	2250	Aroma, taste, color, crumb, texture, etc. satisfactory

[1] Interior section—frozen yeast selected from inner portion of cake (from center to ½" outward).
Exterior section—frozen yeast selected from exterior portion of cake (from surface to ¼" inward).
[2] Sponge and dough fermented at 30° C. and 85% R. H.

TABLE 7

Survival of Various Yeast Strains in 0.85% Sodium Chloride Solution at — 23.5° C.

Strain No.	Source	Yeast cells per cc.; standard plate count 30° C. for 72 hr.						
		Original Count	Storage interval					
			One Week	Two Weeks	Four Weeks	Five Weeks	Six Weeks	Eight Weeks
1	Fresh compressed yeast	15,000,000	2,600,000	600,000	139,000	53,000	.....	.....
2	Fresh dry yeast	1,800,000	52,000	8,000	1,000	500	.....	46
3	Aged compressed yeast abnormally cultured	3,900,000	50,000	4,500	2,000	65	.....	0
4	Aged dry yeast abnormally cultured	1,200,000	10,000	600	40	10	.....	0
5	Pink yeast from frozen berries	2,300,000	700,000	180,000	102,000	77,000	.....	16,000
6	Vegetative yeast cultivated from yeast spores	2,500,000	940,000	.....	72,000	.....	17,000	.....
7	Yeast spores—No. 1	150,000	148,000	156,000	133,000	142,000	.....	120,000
8	Yeast spores—No. 2	1,500,000	1,300,000	.....	1,200,000	.....	1,000,000	.....
9	Yeast spores—No. 3	5,000,000	4,300,000	.....	4,100,000	.....	3,700,000	.....

Strain No.	Source	Yeast cells per cc.; standard plate count 30° C. for 72 hr.						
		Original Count	Storage interval					
			Ten Weeks	Nineteen Weeks	Twenty-three Weeks	Twenty-four Weeks	Thirty-eight Weeks	Fifty-two Weeks
1	Fresh compressed yeast	15,000,000	2,500	.....	33	.....	3	0
2	Fresh dry yeast	1,800,000	20	.....	2	.....	0	0
3	Aged compressed yeast abnormally cultured	3,900,000	.....	.....	.....	.....	0	0
4	Aged dry yeast abnormally cultured	1,200,000	.....	.....	.....	.....	0	0
5	Pink yeast from frozen berries	2,300,000	7,000	.....	50	.....	0	0
6	Vegetative yeast cultivated from yeast spores	2,500,000	.....	15	.....	.....	0	0
7	Yeast spores—No. 1	150,000	110,000	.....	85,000	.....	60,000	32,000
8	Yeast spores—No. 2	1,500,000	.....	540,000	.....	330,000	.....	170,000
9	Yeast spores—No. 3	5,000,000	.....	2,700,000	.....	2,200,000	.....	2,000,000

time was greater than one week. Inasmuch as the unfermented doughs, while not acceptable for making bread, were superior to the fermented doughs, it was thought that the yeast, when subjected to dough fermentation prior to freezing and storage, was less resistant to sub-freezing temperatures than yeast which had been incorporated in a dough and frozen without fermentation of the dough. The later success obtained with freezing and storing roll doughs indicated that the rate of freezing apparently influenced the preserving of the biological activity of the yeast incorporated therein. The bulk size of the bread sponge doughs and insulative material housing the doughs no doubt contributed greatly to slowing down the cooling rate during freezing.

Both the dry and compressed yeasts, which had been recultured in a deficient medium to the point of exhibiting granular reserve material within the thick cell walls, were less resistant to a sub-freezing temperature of — 10° F. (— 23.5° C.) when incorporated in a dough than was normal yeast. As shown in Table 7, these yeasts apparently died off at a faster rate than did normal dry and compressed yeasts when frozen and stored under similar conditions. The bake tests made with abnormal cultured yeasts were of little experimental value except to show that fresh normal yeast cells are, no doube, more cold resistant than aged yeast cells.

The poor results obtained in the bake tests with straight fermented doughs stored at 40° F. (4.5° C.) for two weeks indicated that during storage there occurred possibly an accumulation of fermentation products which were either fungicidal or fungistatic to the yeast. It is likely that contaminating acid-producing micro-organisms augmented the above-mentioned condition by their slow production of these inhibitive substances. Although the simple yeast-flour-water fermented sponges made bread greatly superior to the fermented straight doughs, even after a storage period of 5 weeks at 35° F. (1.5° C), this type of storage over long periods of time would be detrimental to a dough because of the off flavors produced by the slow growth of various contaminating micro-organisms. It is noteworthy, however, that the production of the yeast inhibitive agents apparently was greatly reduced during storage of the simple yeast-flour-water fermented sponges. This decrease in the production of inhibitive agents was to be expected because of the omission of additional fermentable ingredients in a simple yeast-flour-water sponge.

Tables 1, 2, 3, 4, and 5 give the results of baking tests and yeasts counts from the prepared dinner roll doughs. It would appear that the yeast cells in the unfermented doughs were more resistant to low temperature storage and that the yeast cells in the fermented doughs were dying off at a faster rate than those in the unfermented doughs. The yeast counts appeared to support the baking tests for part of the time but as the storage interval lengthened the counts became erratic. Inasmuch as very poor yeast counts showed up in cases (when storage varied from two weeks to three weeks) where a good bake test was obtained, it was thought that the cells had lost their reproductive ability as low temperature storage progressed but still retained fermentative activity. That the death of a proportionate number of the yeast cells did occur during storage is not to be doubted, but that number is not thought to be as high as indicated by plate counts.

The rolls from Series No. 1 (Table 1), were still acceptable after 66 days storage at —10° F. (—23.5° C.), although after 21 days' storage the increase in thaw and pan proof time was more noticeable. Unfermented roll dough stored at 0° F. (— 18° C.) (Series No. 2, Table 2) made an acceptable bake after a storage period of 75 days. However, the increase in thaw and pan proof time was more evident between the second and third weeks' storage periods. Fermented roll dough stored at — 10° F. (— 23.5° C) (Series No. 3, Table 3) showed inferior qualities after 11 and 14 days' storage but the rolls were still acceptable.

The set stored for 21 days was not acceptable and it was necessary to extend the thaw and proofing time to over 3 hours with a resulting low volume product and a much darker crumb and broken down cell structure. Fermented roll dough stored at 0° F. (— 18° C.) (Series No. 4, Table 4), made acceptable rolls after 38 days of storage but not after 61 days of storage. After 61 days of storage a considerable number of yeast cells had either died off or lost their fermentative ability. The first noticeable increase in thaw and pan proof time occurred between the third and fourth weeks' storage.

Through the course of work with roll doughs several factors were observed which could influence results when conducting an experiment of this type. With the fermented roll doughs there was an increase in floor time during the interval each individual panned set of the series was completely packaged and frozen. All panned doughs were placed in the freezing cabinets at the same time and, consequently, those panned and packaged last had very little time to raise during floor time and freezing. Upon removing the frozen doughs from storage some sets were raised more than other sets and it was noticed that those which had little or no floor proofing time prior to freezing produced a better product. From this observation it would appear that the raised doughs had more insulative air pockets which in turn caused a slow-down in their freezing rate. The unfermented roll doughs did not show this characteristic of raising to any noticeable degree and gave more uniform and better baked products.

When comparing Series No. 1 and 3 unfermented and fermented rolls frozen and stored at — 10° F. (— 23.5° C.) against Series No. 2 and 4 frozen and stored at 0° F. (— 18° C), the latter appeared to hold up better although a lower temperature was used in the former case. As shown in Figure 1, the cooling rate of the unfermented rolls of Series No. 1 frozen at — 10° F. (— 23.5° C.) was retarded, since they had been placed in cardboard boxes prior to freezing whereas, the pans of rolls of those frozen at 0° F. (— 18° C.) were placed directly on the metal freezing plates in the freezing cabinet. Although cooling rates were not run on Series No. 3 and 4 fermented roll doughs, it is assumed that those of Series No. 3, which had been placed in a cardboard box in the — 10° F. (— 23.5° C.) cabinet cooled at a slower rate than those of Series No. 4 [frozen in the 0° F. (— 18° C.) cabinet while in direct contact with the cabinet's metal plates]. When the pans con-